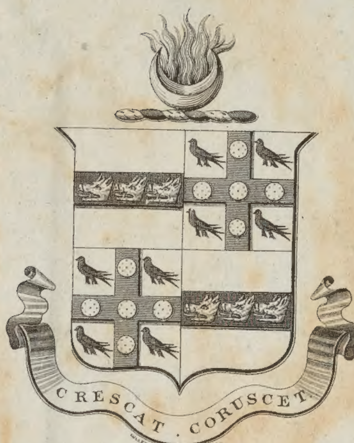

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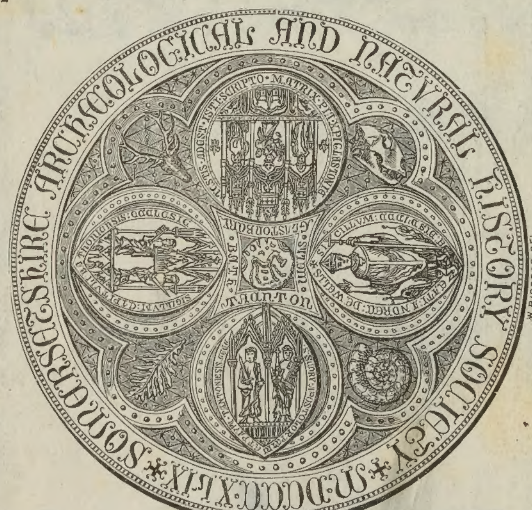

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Personal Narrative
OF TRAVELS
TO THE
EQUINOCTIAL REGIONS
OF THE
NEW CONTINENT,
DURING THE YEARS 1799—1804,

BY

ALEXANDER DE HUMBOLDT,

AND

AIMÉ BONPLAND;

WITH MAPS, PLANS, &c.

WRITTEN IN FRENCH BY

ALEXANDER DE HUMBOLDT,

AND TRANSLATED INTO ENGLISH BY

HELEN MARIA WILLIAMS.

VOL. II.

LONDON:
PRINTED FOR LONGMAN, HURST, REES, ORME, AND BROWN,
PATERNOSTER ROW; J. MURRAY, ALBEMARLE STREET;
AND H. COLBURN, CONDUIT STREET.

1814.

W. Pople, Printer, 67, Chancery Lane.

CONTENTS.

JOURNEY

TO THE

EQUINOCTIAL REGIONS

OF

THE NEW CONTINENT.

CHAPTER III.

Passage from Teneriffe to the coasts of South America.—The Island of Tobago.—Arrival at Cumana.

We left the road of Santa Cruz the evening of the 25th of June, and directed our course towards South America. The wind blew strong from the north-east, and the waves were short, and broken from the opposition of the currents. We soon lost sight of the Canary islands, the lofty mountains of which were covered with a reddish vapour. The Peak alone appeared from time to time in the breaks, as the wind, which must have blown strong in the upper regions of the air, dispersed at

intervals the clouds that enveloped the Piton. We felt for the first time how strong are the impressions left on the mind from the aspect of those countries placed on the limits of the torrid zone, and in which nature appears at once so rich, so various, and so majestic. Our stay at Teneriffe had been very short, and yet we withdrew from the island as if it had been for a long time our home.

Our passage from Santa Cruz to Cumana, the most eastern part of the New Continent, was very fine. We cut the tropic of Cancer the 27th, and though the Pizarro was not a very good sailer, we ran in twenty days the space of nine hundred leagues, which separates the coasts of Africa from those of the New Continent. We passed fifty leagues west of Cape Bajador, Cape Blanco, and the islands of Cape Verd. A few land birds, which had been driven to sea by the impetuosity of the wind, followed us for several days. If we had not exactly known, by our time keepers, our longitude, we should have been tempted to think, that we were very near the coast of Africa.

Our course was such as is taken by all vessels destined for the Antilles since the first voyage of Columbus. The latitude diminished rapidly, almost without gaining in longitude, from the parallel of Madeira to the tropic. When we reach the zone, where the trade winds are constant, we

cross the ocean from east to west, on a calm and pacific sea, which Spanish sailors call the Ladies Gulf, *el Golfo de las Damas*. We found, as all do who frequent those latitudes, that, in proportion as we advance towards the west, the trade winds, which were at first east-north-east, fix to the east.

Those winds, the most generally adopted theory of which is explained in a celebrated treatise of Halley *, are a phænomenon much more complicated † than the greater number of naturalists admit. In the Atlantic Ocean, the longitude as well as the declination of the sun, influences the direction and limits of the trade winds. On the side of the New Continent, in

* The existence of an upper current of air, which blows constantly from the equator to the poles, and of a lower current, which blows from the poles to the equator, had already been admitted, as Mr. Arago has shown, by Hooke. The ideas of the celebrated English naturalist are developed in a discourse on Earthquakes published in 1686. "I think (adds he,) that several phænomena, which are presented by the atmosphere and the ocean, especially the winds, may be explained by the polar currents." (Hooke's Posthumous Works, p. 364.) This curious passage is not cited by Halley (Phil. Trans. vol. xxxix, p. 58). On the other hand, Hooke, speaking directly of the trade winds (Post. Works, p. 88 and 363), adopts the erroneous theory of Galileo, who admits a difference of velocity between the movement of the Earth and that of the air.

† Mém. de l'Acad. 1760, p. 18. D'Alembert, sur les Causes gén. des Vents, p. 5.

both hemispheres, these limits pass the tropics eight or nine degrees; while in the vicinity of Africa the variable winds reign far beyond the parallel of 28 or 27 degrees. It is to be regretted, on account of the progress of meteorology and navigation, that the changes, which the currents of the equinoctial atmosphere in the Pacific Ocean undergo, are much less known, than the variation of these same currents in a sea that is narrower, and influenced by the proximity of the coasts of Guinea and Brazil. Navigators have known for ages past, that in the Atlantic Ocean the equator does not coincide with the line which separates the trade winds of the north-east from the general winds of the south-east. This line, as Halley * has very well observed, is at the third or fourth degree of north latitude; and if its position be the effect of a longer abode of the Sun in the northern hemisphere, it tends to prove, that the temperatures of the two hemispheres † are in the ratio of eleven to nine. We shall see farther on in this work, when we treat of the part of the atmosphere which extends over

* Phil. Trans. vol. xvi, p. 154. Ulloa, Conversaciones, p. 108.

† Prevost, on the limits of the trade winds. Journ. de Phys. t. xxxviii, p. 369. Supposing with Æpinus, that the southern hemisphere is only one fourteenth colder than the northern, the calculation gives, for the northern limit of the E. S. E. trade winds, the parallel of 1° 28′.

the South Sea, that to the west of America the trade winds of the south-east reach to a less distance beyond the equator, than they do in the Atlantic Ocean. In fact the difference, with which the strata of air flow back from the two poles towards the equator, cannot be the same in every degree of longitude, that is to say, on points of the Globe, where the continents have very different breadths, and where they stretch away more or less towards the poles.

It is known, that in the passage from Santa Cruz to Cumana, as in that from Acapulco to the Philippine islands, the sailors are scarcely ever under the necessity of touching the sails. We pass those latitudes, as if we were descending a river, and we might deem it no hazardous undertaking, if we made the voyage in an open boat. Farther west, on the coast of St. Martha, and in the Gulf of Mexico, the trade wind blows impetuously, and renders the sea very stormy *.

The wind fell gradually the farther we removed from the African coasts: it was sometimes smooth water for several hours, and these short calms were regularly interrupted by electrical phænomena. Black thick clouds with strong outlines rose on the east, and it seemed as if a squall

* The Spanish sailors call the rough trade winds at Carthagena in the West Indies *los brisotes de Santa Martha ;* and in the Gulf of Mexico, *las brizas pardas.* These latter winds are accompanied with a gray and cloudy sky.

would have forced us to hand our topsails; but the breeze freshened anew, there fell a few large drops of rain, and the storm was dispersed without our hearing any thunder. It was curious to observe, during this time, the effect of several black, isolated, and very low clouds, which passed the zenith. We felt the force of the wind augment or diminish progressively, according as small bodies of vesicular vapour approached or receded, while the electrometers, furnished with a long metallic rod and lighted match, showed no change of electric tension in the lower strata of the air. It is by means of these squalls, which alternate with dead calms, that the passage from the Canary islands to the Antilles or southern coasts of America is made in the months of June and July. In the torrid zone, the meteorological phænomena follow each other in a very uniform manner; and the year 1803 will be for a long time memorable in the annals of navigation, because several vessels coming from Cadiz to the Caraccas were forced to lie to in the fourteenth degree of latitude, and the forty eighth degree of longitude, on account of a very violent wind, which blew for several days from the north-north-west. What an extraordinary interruption must we suppose in the play of the aerial currents, to explain a cross wind, which without doubt must have deranged at the same time the regularity of the horary oscillations of the barometer!

Some Spanish navigators have lately proposed going to the West Indies and the coasts of Terra Firma, by a different course from that which had been taken by Christopher Columbus. They advise, instead of steering directly to the south in search of the trade winds, to change both latitude and longitude, in a diagonal line from Cape St. Vincent to America. This method, which shortens the way, cutting the tropic nearly twenty degrees west of the point where it is commonly cut by the pilots, has several times been successfully followed by Admiral Gravina. This experienced seaman, who perished gloriously at the battle of Trafalgar, arrived in 1802 at St. Domingo, by the oblique passage, several days before the French fleet, though orders of the court of Madrid would have forced him to enter Ferrol with his squadron, and stop there some time.

This new system of navigation shortens the passage from Cadiz to Cumana a twentieth; but as the tropic is attained only at the longitude of forty degrees, the chance of meeting with contrary winds, which blow sometimes from the south, and at other times from the south-west, is more unfavorable. In the old system, the disadvantage of making a longer passage is compensated by the certainty of finding the trade winds in a shorter space of time, and keeping them the greater part of the passage. At the time of my abode in the Spanish colonies, I witnessed the arrival of seve-

ral merchant ships, which the fear of privateers had determined to choose the oblique course, and that had a very short passage; it is only after repeated trials, that we can decide with certainty on an object, at least as important as the choice of the meridian, at which the equator should be cut in the navigation from Europe to Buenos Ayres or Cape Horn.

Nothing equals the beauty and mildness of the climate of the equinoctial region on the ocean. While the trade wind blew strongly, the thermometer kept at 23 or 24 degrees in the day, and at 22 or 22·5 degrees during the night. To feel the full charm of these happy climates bordering on the equator, the passage from Acapulco or the coasts of Chili to Europe should be undertaken in a very rough season. What a contrast between the tempestuous seas of the northern latitudes, and the regions where the calm of nature is never disturbed! If the return from Mexico or South America to the coasts of Spain were as expeditious and as agreeable as the passage from the old to the new continent, the number of Europeans settled in the colonies would be much less considerable than it is at present. The sea which surrounds the Azores and the Bermuda islands, and which is traversed in returning to Europe by the high latitudes, is called by the Spaniards by the singular name of *Golfo de las Yeguas* (the Mares' Gulf). Colonists who are

not accustomed to the sea, and who have led solitary lives in the forests of Guiana, the savannahs of the Caraccas, or the Cordilleras of Peru, dread the neighbourhood of the Bermudas more than the inhabitants of Lima fear at present the passage round Cape Horn. They exaggerate the danger of a navigation which is perilous only in the winter. They defer from one year to another the execution of a project which appears hazardous, and death very often surprises them in the midst of the preparations which they make for their return.

To the north of the Cape Verd islands we met with great masses of floating sea-weeds. They were the tropic grape, fucus natans, which grows on submarine rocks, only from the equator to the fortieth degree of north and south latitude. These weeds seem to indicate the existence of currents in this place, as well as to the south-west of the banks of Newfoundland. We must not confound the latitudes abounding in scattered weeds with these banks of marine plants, which Columbus compares to extensive meadows, the view of which struck with terror the crew of the Santa Maria in the forty-second degree of longitude. I am assured from the comparison of a great number of journals, that in the basin of the Atlantic Northern Ocean there exist two banks of weeds very different from each other. The most extensive is a little west of the meridian of Fayal, one of the Azores, between the

twenty-fifth and thirty sixth degrees of latitude *. The temperature of the Ocean in those latitudes is from sixteen to twenty degees; and the north winds, which sometimes reign there very tempestuously, drive floating isles of sea-weed down into the low latitudes as far as the parallels of twenty four and even twenty degrees. The vessels which return to Europe, either from Montevideo or the Cape of Good Hope, cross these banks of fucus, which the Spanish pilots consider as at an equal distance from the Antilles and Canaries; and they serve the less instructed mariner to rectify his longitude. The second bank of fucus is but little known; it occupies a much smaller space in the twenty-second and twenty-sixth degrees of latitude, eighty leagues west of the meridian of the Bahama islands. It is found on the passage from the Caiques to the Bermudas.

Though a species of sea-weeds † has been seen

* It appears that Phœnician vessels came "in thirty days sail, with an easterly wind," to the *weedy sea*, which the Portugueze and Spaniards call *mar de zargasso*. I have shown in another place, that the passage of Aristotle, *De Mirabil. ed.* Duval, p. 1157, can scarcely be applied to the coasts of Africa, like an analogous passage of the Periplus of Scylax. *Tableaux de la Nature*, t. 1, p. 98. Supposing that this sea, full of weeds, which impeded the course of the Phœnician vessels, was the *mar de zargasso*, we need not admit, that the ancients traversed the Atlantic beyond thirty degrees of west longitude from the meridian of Paris.

† The *baudreux* of the Falkland islands; fucus giganteus, Forster; laminaria pyrifera, Lamour.

with stems eight hundred feet long, the growth of these marine cryptogamia being extremely rapid, it is not less certain, that, in the latitudes we have just described, the fuci, far from being fixed to the bottom, float in separate masses on the surface of the water. In this state, the vegetation can scarcely continue a longer time than it would do in the branch of a tree torn from its trunk; and in order to explain how moving masses are found for ages in the same position, we must admit, that they owe their origin to submarine rocks, which, placed at forty or sixty fathoms depth, continually supply what has been carried away by the equinoctial currents. This current bears the tropic grape into the high latitudes, toward the coast of Norway and France; and it is not the Gulf Stream, as some mariners think, which accumulates the fucus to the south of the Azores*. It were to be wished, that navigators heaved the lead more frequently in these latitudes covered with weeds: for it is asserted, that Dutch pilots have found a series of shoals from the banks of Newfoundland as far as the coasts of Scotland, by using lines composed of silk thread†.

The causes that unroot these weeds at depths, where it is generally thought the sea is slightly agitated, are not sufficiently known. We learn

* Barrow, Voyage to Cochinchina, vol. 1, p. p. 93.

† Fleurieu, Voy. of the Isis, vol. 1, p. 524. (Labillardiere, Voy. vol. 1, p. 331.)

only, from the luminous observations of M. Lamouroux, that if the fucus adhere to the rocks with the greatest firmness before the display of its fructification, it separates with great facility after this period, or during the season which suspends its vegetation like that of the terrestrial plants. The fish and the molluscas that gnaw the stems of the seaweeds no doubt contribute also to detach them from its roots.

From the twenty-second degree of latitude, we found the surface of the sea covered with flying fish *, which threw themselves up into the air twelve, fifteen, or eighteen feet, and fell down on the deck. I do not hesitate to speak of an object, of which voyagers discourse as frequently as of dolphins, sharks, seasickness, and the phosphorescence of the ocean. None of these objects can fail of affording interesting observations to naturalists, provided they make them their particular study. Nature is an inexhaustible source of investigation, and in proportion as the domain of science is extended, she presents herself to those, who know how to interrogate her, under forms which they have never yet examined.

I have named the flying fish in order to fix the attention of naturalists on the enormous size of their natatory bladder, which, in an animal of 6·4 inches, is 3·6 inches long, 0·9 of an inch broad, and

* Exocœtus volitans.

contains three cubic inches and a half of air. As this bladder takes up more than half the size of the fish, it is probable that it contributes to its lightness. We may assert, that this reservoir of air is more fitted for flying than swimming; for the experiments * made by Mr. Provenzal and myself, have proved, that, even in the species which are provided with this organ, it is not indispensably necessary for the movements of ascension towards the surface of the water. In a young flying-fish 5·8 inches long, each of the pectoral fins, which serve as wings, presented a surface to the air of 3·7 square inches. We observed, that the nine branches of nerves, which go to the twelve rays of these fins, are almost three times the size of the nerves that belong to the ventral fins. When the former of these nerves are excited by galvanic electricity, the rays which support the membrane of the pectoral fin extend with five times the force with which the other fins move when galvanized by the same metals. By these means the fish is capable of throwing itself horizontally twenty feet distance, before retouching the water with the extremity of its fins. This motion has been aptly compared to that of a flat stone, which, thrown horizontally, bounds one or two feet above the water. Notwithstanding the extreme rapidity

* Researches on the respiration of fishes, and their air-bladder, in the Mémoires de la Société d'Arcueil, vol. ii, p. 359.

of this motion, it is certain, that the animal beats the air during the leap, that is, it alternately extends and closes its pectoral fins. The same motion * has been observed in the flying scorpæna of the rivers of Japan, which contains also a large air-bladder, with which the great part of the scorpænæ, that have not the faculty of flying, are unprovided †. The flying-fish, like almost all animals which have gills, enjoy the privilege ‡ of equal respiration for a long time both in water and in air, by the same organs; that is by extracting the oxygen from the atmosphere as well as from the water in which it is dissolved. They pass a great part of their life in the air, but this life is at best but an unhappy one. If they escape from the sea to avoid the voracity of the dolphin, they meet in the air men-of-war birds, albatrosses, and other birds, which seize them in their flight. Thus, on the banks of the Orinoco, herds of river cavies §, that rush from the water to escape the crocodile, become the prey of the jaguar, which awaits their arrival.

I doubt, however, if the flying fish spring out of the water merely to escape the pursuit of their enemies. Like swallows, they move by

* Lacepède, Histoire naturelle des Poissons, vol. iii. p. 290.

† S. porcus, s. scrofa, s. dactyloptera. Delaroche, Ann. des Mus. t. 14, p. 189.

‡ Mém. d'Arcueil, t. ii. p. 397.

§ Cavia capybara, L. Thick-nosed tapir, Pennant.

thousands in a right line, and in a direction constantly opposite to that of the waves. In our own climates, on the brink of a river, the limpid waters of which are illumined by the rays of the sun, we often see solitary fish, with no motive of fear, bound above the surface, as if they felt pleasure in breathing the air. Why should not these gambols be more frequent with the flying-fish, which from the strength of their pectoral fins, and the smallness of their specific gravity *, can so easily support themselves in the air? I invite naturalists to examine whether other flying fish, for instance the exocœtus exiliens, the trigla volitans, and the t. hirundo, have as capacious an air-bladder as the flying-fish of the tropics. This last follows the heated waters of the gulf stream when they flow towards the north. The ship boys amuse themselves with cutting off a part of the pectoral fins, and assert, that these wings grow again; which seems to me not unlikely, from facts observed in other families of fishes.

At the time I left Paris, experiments made at Jamaica, by Dr. Brodbelt †, on the air contained in the natatory bladder of the sword-fish ‡, had made some naturalists think, that under the

* Cuvier, in the Ann. du Mus. t. 14, p. 165; and Delaroche, ibid. p. 262 (note).

† Duncan's Ann. of Medicine, 1796, p. 393. Nicholson's Journ. of Nat. Phil., 4to ed., vol. i, p. 264.

‡ Xiphias gladius. Lin.

tropics, in the sea fish, this organ was filled with pure oxygen gas. Full of this idea, I was surprised at finding in the air-bladder of the flying-fish only 0·04 of oxygen to 0·94 of azot and 0·2 of carbonic acid. The proportion of this last gas, measured by the absorption of lime water in graduated tubes*, appeared more constant than that of the oxygen, of which some individuals yielded almost double the quantity. From the curious phænomena observed by M. Biot, Configliachi, and Delaroche †, we might suppose, that the sword fish dissected by Dr. Brodbelt had inhabited the lower strata of the ocean, where some fish ‡ have as much as 0·92 of oxygen in their air-bladder.

* Anthracometers, curved tubes with a large ball. See my Essays on the atmosphere, plate 1 (German).

† Mém. d'Arcueil, vol. i, p. 257. Ann. du Mus. t. 14, p. 184—217 and 245—289. Configliachi sull' Analisi dell' Aria contenuta nella Vesica natatoria, Pavia, 1809. Having employed eight months in experiments on the respiration of fishes, M. Provenzal and myself observed, that the fishes absorbed not only oxygen, but also azot, and that the quantity of this azot absorbed differs in individuals of the same species. The oxygen inhaled was very far from being equalled by the carbonic acid, which the fish exhale from the whole surface of their body; and these facts tend to prove, that the proportion of oxygen and azot vary in the air-vessel, according as the vital action of the gills and the skin is modified by the greater or less pressure, which the fish undergoes at different depths.

‡ Trigla cucullus.

The 1st of July in 17° 42′ latitude and 34° 21′ longitude, we met with the wreck of a vessel, of which we distinguished the mast covered with floating sea-weed. This shipwreck could not have taken place in a zone where the sea is constantly calm. The wreck came perhaps from the stormy seas of the north, and might be driven back to the point where the vessel had perished, carried on by that extraordinary whirl which the waters of the Atlantic undergo in the northern hemisphere.

On the 3d and 4th, we crossed that part of the ocean, where the charts indicate the bank * of the Maal-stroom; toward night we altered our course to avoid this danger, the existence of which is as doubtful as that of the isles Fonseco and St. Anne †. It would have been perhaps as

* Borda, Voyage de la Flore, vol. ii, p. 314.

† Jeffery's and Van-Keulen's charts indicate four islands, which are only imaginary dangers: the islands Garca and St. Anne, to the west of the Azores; the Green island (latitude 44° 52′, longitude 28° 30′) and the isle of Fonseco (latitude 13° 15′, longitude 57° 10′). How is it possible to believe in the existence of four islands in latitudes crossed by thousands of vessels, when of so many small rocks and shoals, announced by credulous pilots for a century past, there are scarcely above two or three that are real? As to the general question, what is the degree of probability we may admit, that an islet visible at the distance of a league may be discovered between America and Europe, we might submit this to a rigorous calculation, if we knew the number of ships that have

prudent to have continued our course. The old charts are filled with rocks, some of which really exist, but the greater part are owing to those optical illusions, which are more frequent at sea than in inland countries. The position of the real dangers is generally indicated by chance; they have been seen by pilots who were several degrees out in their longitude, and we might be certain of meeting neither with rocks nor breakers, if we directed our course towards the points where they are laid down on the maps. As we approached this pretended Maal-stroom, we observed no other motion in the waters than the effect of a current which bore to the north west, and which hindered us from diminishing our latitude as much as we wished. The force of this current augments as we approach the new continent; it is modified by the configuration of the coasts of Brazil and Guiana, and not by the waters of the Orinoco and the Amazons, as some naturalists pretend.

From the time we entered the torrid zone, we were never wearied with admiring, every night, the beauty of the southern sky, which, as we advanced towards the south, opened new constellations to our view. We feel an indescribable sensation,

annually crossed the Atlantic these three centuries past, and if regard be had to the unequal distribution of those vessels in different latitudes. If the Maal-Stroom were, as Van Keulen admits, in 16° of latitude and 39° 30′ of longitude, we should have crossed it the 4th of June.

when, on approaching the equator, and particularly on passing from one hemisphere to the other, we see those stars, which we have contemplated from our infancy, progressively sink, and finally disappear. Nothing awakens in the traveller a livelier remembrance of the immense distance by which he is separated from his country, than the aspect of an unknown firmament. The grouping of the stars of the first magnitude, some scattered nebulæ, rivalling in splendor the milky way, and tracks of space remarkable for their extreme blackness, give a particular physiognomy to the southern sky. This sight fills with admiration even those, who, uninstructed in the branches of accurate science, feel the same emotion of delight in the contemplation of the heavenly vault, as in the view of a beautiful landscape, or a majestic site. A traveller has no need of being a botanist, to recognize the torrid zone on the mere aspect of its vegetation; and without having acquired any notions of astronomy, without any acquaintance with the celestial charts of Flamstead and de la Caille, he feels he is not in Europe, when he sees the immense constellation of the Ship, or the phosphorescent clouds of Magellan, arise on the horizon. The heaven, and the earth, every thing in the equinoctial regions, assumes an exotic character.

The lower regions of the air were loaded with vapors for some days. We saw distinctly for the

first time the Cross of the south only in the night of the 4th and 5th of July, in the sixteenth degree of latitude; it was strongly inclined, and appeared from time to time between the clouds, the centre of which, furrowed by uncondensed lightnings, reflected a silver light. If a traveller may be permitted to speak of his personal emotions, I shall add, that in this night I saw one of the reveries of my earliest youth accomplished.

When we begin to fix our eyes on geographical maps, and read the narratives of navigators, we feel for certain countries and climates a sort of predilection, for which we know not how to account at a more advanced period of life. These impressions, however, exercise a considerable influence over our determinations; and from a sort of instinct we endeavour to connect ourselves with objects, on which the mind has long been fixed as by a secret charm. At a period when I studied the heavens, not with the intention of devoting myself to astronomy, but only to acquire a knowledge of the stars, I was agitated by a fear unknown to those who love a sedentary life. It seemed painful to me to renounce the hope of beholding those beautiful constellations, which border the southern pole. Impatient to rove in the equinoctial regions, I could not raise my eyes towards the starry vault without thinking of the Cross of the South, and without recalling the sub-

lime passage of Dante, which the most celebrated commentators have applied to this constellation;

> Io mi volsi a man destra e posi mente
> All' altro polo e vidi quattro stelle
> Non viste mai fuor ch' alla prima gente.
>
> Goder parca lo ciel di lor fiammelle;
> O settentrional vedovo sito
> Poi che privato se' di mirar quelle!

The pleasure we felt on discovering the southern Cross was warmly shared by such of the crew as had lived in the colonies. In the solitude of the seas, we hail a star as a friend, from whom we have long been separated. Among the Portuguese and the Spaniards peculiar motives seem to increase this feeling; a religious sentiment attaches them to a constellation, the form of which recalls the sign of the faith planted by their ancestors in the deserts of the new world.

The two great stars which mark the summit and the foot of the Cross having nearly the same right ascension, it follows hence, that the constellation is almost perpendicular at the moment when it passes the meridian. This circumstance is known to every nation, that lives beyond the tropics, or in the southern hemisphere. It has been observed at what hour of the night, in different seasons, the Cross of the south is erect, or inclined. It is a time-piece that advances very regularly near four minutes a day, and no other

group of stars exhibits, to the naked eye, an observation of time so easily made. How often have we heard our guides exclaim in the savannas of Venezuela, or in the desert extending from Lima to Truxillo, "Midnight is past, the Cross begins to bend!" How often those words reminded us of that affecting scene, where Paul and Virginia, seated near the source of the river of Lataniers, conversed together for the last time, and where the old man, at the sight of the southern Cross, warns them that it is time to separate.

The last days of our passage were not so happy, as the mildness of the climate, and the calmness of the ocean, had led us to hope. The dangers of the sea did not disturb our enjoyments, but the germe of a malignant fever discovered itself as we drew near the Antilles. Between decks the ship was excessively hot, and very much encumbered. From the time we passed the tropic, the thermometer was at thirty-four or thirty-six degrees. Two sailors, several passengers, and, what is remarkable enough, two negroes from the coast of Guinea, and a mulatto child, were attacked with a disorder which appeared epidemic. The symptoms were not equally alarming in them all; nevertheless, several persons, and especially the most robust, fell into a delirium after the second day, and felt a total prostration of their strength. The indifference which prevails on board packet

boats, for every thing that does not regard the working of the ship, and the quickness of the passage, prevented the captain from employing the ordinary means of diminishing the danger which threatened us. No fumigation was made. A Gallician surgeon, ignorant and phlegmatic, ordered bleedings, because he attributed the fever to what he called heat and corruption of the blood. There was not an ounce of bark on board; we had forgot to take any with us, because, being more occupied with our instruments than our health, we thought too carelessly, that this salutary production of Peru could not fail to be found on board a Spanish vessel.

The 8th of July, a sailor, who was near expiring, recovered his health from a circumstance that is worthy of being mentioned. His hammock was so hung, that there was not ten inches between his face and the deck. It was impossible to administer the sacraments in this situation; for, agreeably to the custom aboard Spanish vessels, the viaticum ought to be carried by the light of tapers, and followed by the whole crew. The patient was removed into an airy place, near the hatchway, where a small square birth had been formed with sail cloth. Here he was to remain till he died, which was an event expected every moment; but passing from an air extremely heated, stagnant, and filled with miasms into fresher and purer air, which was renewed

every instant, he gradually revived from his lethargic state. His recovery dated from the day when he quitted the middle deck; and as often in medicine the same facts are cited in support of systems diametrically opposite; this recovery confirmed our doctor in his ideas of the inflammation of the blood, and the necessity of bleeding, evacuating, and all the asthenic remedies. We soon felt the fatal effects of this treatment; and wished more than ever to reach the coasts of America.

For several days the pilot's reckoning differed 1° 12′ in longitude from that of my time-keeper. This difference was owing less to the general current, which I have called the *current of rotation*, than to that particular movement, which, drawing the waters toward the north-west, from the coast of Brazil to the Antilles, shortens the passage from Cayenne to Guadaloupe*. The 12th of July, I thought I might foretell our seeing land the next day before sunrise. We found ourselves then, according to my observations, in latitude 10° 46′, and west longitude 60° 54′. A few series of lunar distances confirmed the chronometrical result; but we were surer of the position of the

* In the Atlantic Ocean there is a space, where the water is constantly milky, though the sea is very deep. This curious phænomenon exists in the parallel of the island of Dominica, very near the 57th degree of longitude. May there not be in this place some sunk volcanic islet, more easterly still than Barbadoes?

vessel, than of that of the land to which we directed our course, and which was so differently placed in the French, Spanish, and English charts. The longitudes, deduced from the accurate observations of Messrs. Churruca, Fidalgo, and Noguera, were not published at this period.

The pilots trusted more to the log than the timekeeper; they smiled at the prediction of speedily making the land, and thought themselves two or three days sail from the coast. It was therefore with great pleasure, that on the 13th, toward six in the morning, I learnt that very high land was seen from the mast-head, though not clearly, as it was surrounded with a thick fog. The wind blew hard, and the sea was very rough. Large drops of rain fell at intervals, and every appearance menaced tempestuous weather. The captain of the Pizarro intended to pass through the channel, which separates the isle of Tobago from that of Trinidad; and knowing that our sloop was very slow in tacking, he was afraid of falling to leeward toward the south, and approaching the Bocca-del-Drago. We were in fact surer of our longitude than of our latitude, having had no observation at noon since the 11th. Double altitudes which I took in the morning, after Douwes's method, placed us in 11° 6′ 50″, consequently 15′ north of our reckoning. The impetuosity, with which the great river Orinoco throws its waters into the ocean, may undoubtedly, in these latitudes, increase the

strength of the currents; but what has been stated respecting the change of color and the saltness of the water, at sixty leagues from the mouth of the Orinoco, is a fable invented by the coasting pilots. The influence of the most considerable rivers of America, such as the Amazons, the Plata, the Orinoco, the Mississipi, and the Magdalena, is restricted, in this respect, within much narrower limits than is generally thought.

Although the result of the double altitudes of the sun proved clearly, that the high land in the horizon was not Trinidad, but Tobago, the captain continued to steer N N W, in search of this latter island, which, even in Borda's chart, is placed 5′ too far south. We can scarcely believe, that on coasts frequented by every trading nation, such enormous errors in latitude should be thus perpetuated for ages. Having discussed this matter in another place *, it is sufficient here to observe, that even in the last chart of the West Indies, published by Mr. Arrowsmith, in 1803, consequently a long time after the labours of Churruca, the latitudes of the different capes of Tobago and Trinidad, are still from six to eleven minutes erroneous.

An observation of the meridian altitude of the Sun fully confirmed the latitude obtained by

* Obs. Ast. p. 35 to 39, and Introduction, p. 38. (Chart of the Atlantic Ocean. Sixth edition.)

Douwes's method. No more doubt remained respecting the position of the vessel, with respect to the island, and we resolved to double Cape North in Tobago to pass between this island and Grenada, and steer towards a port in Margaretta. In these latitudes we ran at every moment the risk of being taken by privateers; but happily for us the sea was very rough, and a small English cutter passed without hailing us. As to M. Bonpland and myself, we were less afraid of this, since, as we were so near the continent of America, we were sure of not being carried back to Europe.

The island of Tobago presents itself under a very picturesque aspect. It is a heap of rocks carefully cultivated. The dazzling whiteness of the stone forms an agreeable contrast with the verdure of some scattered tufts of trees. Cylindric and very lofty opuntia crown the top of the mountains, and give a peculiar physiognomy to this tropical landscape. Their sight alone is sufficient to remind the navigator, that he has arrived at an American coast; for cactuses are exclusively peculiar to the New World, as heaths to the Old *. The north-west part of the island of Tobago is the least mountainous; according to the angles of height, taken with the sextant, the most lofty points of the coast do not appear to exceed 140 or

* Essay on the Physiognomy of Plants. See my Views of Nature, vol. i, p. 47.

150 toises. At South-west Cape, the land descends towards Sandy Point, the latitude of which I found to be 10° 20′ 13″, and the longitude 62° 47′ 30″. We perceived several rocks on a level with the water, on which the sea broke violently, and we distinguished a great regularity in the inclination and direction of the strata, which dip to the south-west at an angle of 60°. It were to be wished, that the tour of the West Indies, from the coast of Paria to Cape Florida, were made by a good mineralogist, who would examine this ancient chain of mountains broken by the action of currents, earthquakes, and volcanoes.

After having doubled the north cape of Tobago, and the small island of St. Giles, we were alarmed with the news of an enemy's squadron seen from the mast-head; the passengers were in the utmost consternation, for several had laid out their small fortunes in goods, which they counted on selling in the Spanish colonies. The squadron seemed motionless, and we soon discovered, that what we had taken for ships was a multitude of separate rocks*.

We crossed the shoal which joins Tobago to the island of Grenada. The color of the sea had no visible change: but the centigrade thermometer, plunged into the water at some inches depth, rose

* Perhaps the rocks called the *Hermanas* (the Sisters).

only to 23°; while farther at sea eastward on the same parallel, and equally near the surface, it kept at 25·6°. Notwithstanding the currents, the cooling of the water indicated the existence of the shoal, which is noted but in a small number of charts. The wind slacked after sunset, and the clouds disappeared as the moon reached the zenith. The number of falling stars was very considerable both this and the following nights; they appeared less frequent towards the north than the south over Terra Firma, which we began to coast. This position seems to prove the influence of local causes on meteors, the nature of which is not yet sufficiently known to us.

The 14th at sunrise, we were in sight of the Bocca-del-Drago. We distinguished the island Chacachacarreo, the most westerly of those islands which are placed between Cape Paria and the north-west cape of Trinidad. When we were five leagues distant from the coast, we felt, near *Punta de la Baca,* the effect of a particular current, which drew the ship toward the south. The motion of the waters which flow through the Bocca-del-Drago, and the action of the tides, occasion an eddy. We hove the lead, and found from thirty-six to forty-three fathoms on a bottom of very fine green clay. According to the rules established by Dampier *, we ought not to have

* Voyage round the World, vol. ii, p. 476.

expected so little depth near a coast formed by very high and perpendicular mountains. We continued to heave the lead till we reached *Cabo de tres Puntas,* and we every where found shallow water, apparently indicating the prolongation of the ancient coast. In these latitudes the temperature of the sea was twenty-three or twenty-four degrees, consequently from 1·5 to two degrees less than in the open ocean, beyond the edges of the bank.

Cape Three Points, the name given to it by Columbus himself*, is, according to my observations, in 65° 4′ 5″ longitude. It seemed to us so much the more elevated, as the clouds concealed from us the view of its indented top. The physiognomy of the mountains of Paria, their color, and especially their generally rounded forms, made us suspect, that the coast was granitic; but we afterward recognized how delusive, even for those who have passed their lives in scaling mountains, are opinions respecting the nature of rocks seen at a distance.

A dead calm, which lasted several hours, permitted us to determine with exactness the intensity of the magnetic forces opposite the *Cabo de tres Puntas.* This intensity was greater than in the open sea, to the east of the island of Tobago, in the ratio of 237 to 229. During the calm the

* Month of August, 1598.

current drew us on rapidly to the west. Its velocity was three miles an hour, and increased as we approached the meridian of *Testigos*, a heap of rocks which rise up amidst the waters. At the setting of the Moon, the sky was covered with clouds, the wind freshened anew, and the rain descended in one of those torrents, which are peculiar to the torrid zone, and to which we were often exposed during our inland excursions.

The malady which had broke out on board the Pizarro had made rapid progress, from the time we came on the coasts: the thermometer kept regularly during the night between twenty-two and twenty-three degrees, and during the day from twenty-four to twenty-seven. The congestions toward the head, excessive dryness of the skin, extreme weakness, all the symptoms grew more alarming; but having almost reached the end of our voyage, we flattered ourselves, that all who were sick would be restored to health, as soon as we could land them at the isle of St. Margaretta, or the port of Cumana, distinguished for their great salubrity.

This hope was not altogether realised. The youngest of the passengers attacked with the malignant fever was happily the first and only victim. He was an Asturian, nineteen years of age, the only son of a poor widow. Several circumstances rendered the death of this young man affecting. His features bore the marks of sensi-

bility, and a great mildness of disposition; he had embarked against his inclination, and his mother, whom he had hoped to assist by the produce of his labors, had sacrificed her own tenderness to the idea of securing the fortune of her son, by sending him to the colonies to a rich relation, who resided at the isle of Cuba. The unfortunate young man expired the third day of his illness, having fallen from the beginning into a lethargic state interrupted by fits of delirium. The yellow fever, or black vomiting, at Vera Cruz, scarcely carries off the sick with so alarming a rapidity. Another Asturian, still younger, did not leave one moment the bed of his dying friend, and, what is very remarkable, did not contract the disorder. He was to follow his countryman to St. Jago de Cuba, by whom he was to be introduced to the house of this relation, on whom all their hopes depended. Nothing could be more affecting than the sorrow of him who had survived his friend, and who bewailed with bitterness the fatal counsels, which had thrown him on a foreign climate, where he found himself abandoned, and without support.

We were assembled on the deck, absorbed in melancholy reflections. It was no longer doubtful, that the fever which raged on board had assumed in these last days a fatal aspect. Our eyes were fixed on a hilly and desert coast, on which the Moon, from time to time, shed its light

athwart the clouds. The sea, gently agitated, shone with a feeble phosphoric glittering. Nothing was heard but the monotonous cry of a few large sea-birds, flying towards the shore. A profound calm reigned over these solitary abodes, but this calm of nature was in discordance with the painful feelings by which we were oppressed. About eight the dead man's knell was slowly tolled; at this lugubrious sound, the sailors ceased their labor, and threw themselves on their knees to offer a momentary prayer; an affecting ceremony, which, while it brought to our remembrance those times, when the primitive christians considered themselves as members of the same family, seemed to blend mankind into one common feeling from the sentiment of a common evil. The corpse of the Asturian was brought upon deck during the night, and the priest entreated, that it might not be committed to the waves till after sunrise, in order to pay it the last rites, according to the usage of the Romish church. There was not an individual on board, who did not sympathise with the fate of this young man, whom we had beheld, but a few days before, full of cheerfulness and health.

The event I have just related proved the danger of this malignant fever*, the victims of which,

* *Typhus*, Sauvages; *Febris nervosa*, Frank.

we apprehended, might be very numerous, if a continuance of calms should lengthen the passage from Cumana to the Havannah. On board a ship of war, or a transport, the death of a few individuals commonly makes no more impression, than the sight of a funeral procession in a populous city: not so on board a packet, the crew of which are few in number, and where the persons who have the same end in view form habits of intimacy with each other. The passengers of the Pizarro, who had not yet felt the symptoms of the disease, resolved to leave the vessel at the first place where she touched, and wait the arrival of another packet, to pursue their course to the island of Cuba and to Mexico. They considered the between decks of the ship as pestiferous; and though it was by no means clear to me, that the fever was contagious from contact*, I thought it most prudent to land at Cumana. I wished not to visit New Spain, till I had made some abode on the coasts of Venezuela and Paria; a small number of the productions of which had been examined by the unfortunate Loefling. We were anxious to behold in

* The sailor of whom I have just spoken, and who escaped death by the change of air, was but slightly indisposed when he came on board at Corunna; it was no donbt from some peculiar disposition of his organs, that he was first attacked with the malignant fever, when we entered the torrid zone.

their native site the beautiful plants, which Bose and Bredemeyer had collected during their journey to the continent, and which adorn the green-houses of Schoenbrunn and Vienna. It would have been painful to have touched at Cumana, or at Guayra, without visiting the interior of a country so little frequented by naturalists.

The resolution we took during the night of the 14th and 15th of July had a happy influence on the direction of our travels. Instead of a few weeks, we remained a whole year in this part of the continent; had not the fever raged on board the Pizarro, we should never have reached the Orinoco, the Cassiquiare, and even the limits of the Portuguese possessions on the Rio Negro. We were also indebted perhaps to this direction given to our travels for the state of health we enjoyed during so long an abode in the equinoctial regions.

It is well known, that Europeans, during the first months after their arrival under the scorching sky of the tropics, are exposed to the greatest dangers. They consider themselves as seasoned, when they have passed the rainy season in the West India islands, at Vera Cruz, or at Carthagena. This opinion is very general, although there are examples of persons, who, having escaped a first attack of the yellow fever, have perished victims of the same disease in one of the following years. The facility of being seasoned

seems to be in the inverse ratio of the difference that exists between the mean temperature of the torrid zone, and that of the country in which the traveller, or planter, who changes his climate, is born; because the irritability of the organs, and their vital action, are powerfully modified by the influence of the atmospheric heat. A Prussian, a Polander, or a Swede, is more exposed on their arrival at the islands or on the continent, than a Spaniard, an Italian, or even an inhabitant of the South of France*. With respect to the people of the north, the difference of the mean temperature is from nineteen to twenty-one degrees, while to the people of southern countries it is only from nine to ten. We were fortunate enough to pass the time, when a European recently landed runs the greatest danger, in the extremely hot, but very dry climate of Cumana, a city celebrated for its salubrity. Had we continued our voyage to Vera Cruz, we should perhaps have shared in the unhappy fate of several passengers of the packet boat, the Alcudia, which arrived at the Havanna with the Pizarro, at a period when the black vomiting made such cruel ravages in the island of Cuba, and on the eastern coasts of Mexico.

The 15th, in the morning, when nearly abreast of the hill of St. Joseph, we were surrounded by

* New Spain, vol. ii, p. 754.

a great quantity of floating sea weed. Its stems had those extraordinary appendages in the form of little cups and feathers, which Don Hippolyto Ruiz remarked on his return from the expedition to Chili, and which he described in a separate memoir as the sexual organs of the fucus natans. A fortunate accident allowed us the means of verifying a fact, which had been but once observed by naturalists. The bundles of fucus collected by M. Bonpland were completely identical with the specimens given us by the learned authors of the Flora of Peru. On examining both with the microscope, we found, that these pretended parts of fructification, these stamina and pistils, belong to a new genus of the family of the ceratophytæ. The small cups, which Mr. Ruiz took for pistils, proceed from horny and flattened stems, which are so intimately united to the substance of the fucus, that we might be tempted to take them for mere fasciculated fibres; but these horny stems may be separated by a very thin blade, without hurting the parenchyma. They are unarticulated, and at first of a dark brown; but they become in time, by drying, white and friable; in this state they effervesce with acids, as the calcareous substance of the sertularia, the extremities of which very much resemble the cups of the fucus of Mr. Ruiz. We found again, in the South Sea, on our voyage from Guayaquil to Acapulco, these same appen-

dages to the tropic grape, and the most attentive examination left us no doubt, that a zoophyte is attached to the fucus, as ivy entwines the trunks of trees. The organs described under the name of female flowers are more than two lines long, and their size alone should have removed the suspicion, that these parts were real pistils.

The coast of Paria stretches to the west, forming a wall of rocks of no great height, with rounded tops and a waving outline. We were long without perceiving the bold coasts of the island of Margaretta, where we were to stop in order to obtain information respecting the English cruizers, and the danger of touching at Guayra. We had learnt by altitudes of the sun, taken under very favorable circumstances, how incorrect at this period were the most esteemed marine charts. On the fifteenth in the morning, when the time keeper placed us in 66° 1′ 15″ longitude, we were not yet in the meridian of Margaretta island; though according to the reduced chart of the Atlantic ocean* we ought to have passed the very lofty western cape of this island, which is laid down in longitude 66°. The inaccuracy with which the coasts were delineated previous to the works of Messrs. Fidalgo, Noguera, and Tiscar†, and I

* Constructed at the Depôt de la Marine in 1786, and corrected in 1792.

† *Carta general del oceano Atlantico construida en el Depo-*

may venture to add, before the astronomical observations I made at Cumana, might have become dangerous to navigators, were not the sea uniformly calm in those regions. The errors in latitude were still greater than those in longitude, since the coasts of New Andalusia stretch to the westward of Cape Three Points fifteen or twenty miles more to the north, than appears in the charts published before the year 1800.

Toward eleven in the morning, we perceived a very low islet, covered with a few sandy downs ; and on which we discovered with our glasses no trace

sito hydrógraphico de Madrid en el anno 1800, *et corregida en* 1804. *Carta esferica de las Islas Antillas con parte de la costa del continente de America, trabajada por Don Cosme Churruca y Don Joacquin Francisco Fidalgo*, 1802. These two charts have served as bases to all those that have appeared in these latter times in different parts of Europe, which, copied one from another, differ only in numberless chalcographical errors. Most of the original observations of the Spanish astronomers are mentioned in Mr. Espinosa's valuable work, entitled *Memorias sobre las Observaciones astronomicas hechas por los Navegantes Espannoles en distintos Lugares del Globo* (2 vols, 4to, Madrid, 1809). I have compared, step by step, the results of these observations with those on which Mr. Oltmann and myself are agreed (*Astron. Obs.* vol. 1 ; *Introd.* p. 33—49). This comparison will be useful to those, who may hereafter publish charts of America ; the new determinations deserving so much the more confidence, as the positions have been verified by very different astronomical methods, and by observers who did not communicate their results to each other, till long after they had terminated their labours.

of habitation or culture. Cylindrical cactuses rose here and there in the form of candelabra. The soil, almost destitute of vegetation, seemed to have a waving motion, in consequence of the extraordinary refraction, which the rays of the sun undergo in traversing the strata of air in contact with plains strongly heated. Under every zone, deserts and sandy shores appear like an agitated sea, from the effect of looming.

The appearance of so flat a country scarcely corresponded with the ideas we had formed of the island of Margaretta. While we were busy in laying down our bearings on the charts, and unable to make them correspond, a few small fishing boats were descried from the mast-head. The captain of the Pizarro fired a gun for them; but this signal was useless on a coast where the weak apprehend that they meet with the strong only to be insulted. The boats hastened away toward the west, and we found ourselves in the same perplexity as we had been with respect to the small island of Graciosa, on our arrival at the Canaries. No person on board had landed on this spot, or could give us any information respecting it. Though the sea was very calm, the proximity of an islet, which rose scarcely a few feet above the surface of the water, seemed to prescribe measures of prudence. We ceased to stand toward the land; and as the lead gave but three or four fathoms, we speedily let go an anchor.

The coasts, seen at a distance, are like clouds, in which each observer meets the form of the objects that occupy his imagination. Our bearings and our chronometer being at variance with the charts which we had to consult, we were lost in vain conjectures. Some took mounds of sand for Indian huts, and pointed out the place, where, according to them, the fort of Pampatar was situate; others saw herds of goats, which are so common in the dry valley of St. John; or descried the lofty mountains of Macanao, which seemed to them partly hidden by the clouds. The captain resolved to send a pilot on shore, and the men were preparing to hoist out the long-boat, the cutter having been damaged by the surge in the road of Santa Cruz; but the coast being still far off, the return of the boat might have become difficult, if the breeze had freshened toward evening.

At the moment we were preparing to go on shore, we perceived two canoes sailing along the coast. Again we fired a gun as a signal for these; and though we had hoisted Spanish colours, they drew near with distrust. These canoes, like all those made use of by the natives, were constructed of the single trunk of a tree; and in each were eighteen Guayqueria Indians, naked to the waist, of very tall stature. They had the appearance of great muscular strength, and the colour of their skin was something between a brown and a copper colour. Seen at a distance, motionless in their

attitudes, and projected on the horizon, they might have been taken for statues of bronze. We were so much the more struck with this aspect, as it did not correspond with the ideas we had formed from the accounts of travellers of the characteristic features and extreme weakness of the natives. We afterward learnt, without passing the limits of the province of Cumana, the great contrast that exists between the physiognomy of the Guayquerias and that of the Chaymas and the Caribs. Notwithstanding the intimate ties, which appear to unite the whole of the American nations as belonging to the same race, several tribes do not the less differ from each other in the height of their stature, their complexion more or less tawny, and their looks, which in some express tranquillity and mildness, in others a sinister mixture of melancholy and ferocity.

When we were near enough to hail them in Spanish, the Indians threw aside their mistrust, and came straight on board. They informed us, that the low islet near which we were at anchor was that of Coche, which had never been inhabited; and that the Spanish vessels coming from Europe were accustomed to sail farther north, between this island and that of Margaretta, to take a coasting pilot at the port of Pampatar. Our inexperience had led us into the channel to the south of Coche; and as at this period the English cruisers frequented this passage, the Indians had

taken us for an enemy's ship. The southern passage is in fact highly advantageous for vessels going to Cumana and Barcelona: it has less water than the northern passage, which is much narrower; but there is no risk of touching the ground, if vessels keep very close to the island of Lobos and the Moros del Tunal. The channel between Coche and Margaretta is narrowed by the shoals off the north-west cape of Coche, and by the bank that surrounds la Punta de Mangles. We shall examine in another place, under a geological point of view, this bank of sand, which surrounds the rocks of Testigos and Margaretta; and shall show. that the latter island was formerly united, by means of Coche and Lobos, to the peninsula of Chacopapa.

The Guayquerias belong to that tribe of civilized Indians, who inhabit the coasts of Margaretta, and the suburbs of the city of Cumana. Next to the Caribs of Spanish Guyana, it is the finest race of men in Terra Firma. They enjoy several privileges, because from the earliest times of the conquest they remained faithful friends to the Castilians. The king of Spain names them in his public acts, "his dear, noble, and loyal Guayquerias." The Indians of the two canoes we had met had left the port of Cumana during the night. They were going in search of timber to the cedar*

* Cedrela odorata, Lin.

forests, which extend from Cape San Jose farther than the mouth of Rio Carupano. They gave us some fresh cocoa nuts, and very beautifully colored fish of the chætodon genus *. What riches to our eyes were contained in the canoes of these poor Indians! Broad spreading leaves of vijao † covered bunches of plantains. The scaly cuirass of an armadillo ‡, the fruit of the calabash tree, crescentia cujete, used as a cup by the natives, the productions most common in the cabinets of Europe, had a peculiar charm for us, because they reminded us, that, having reached the torrid zone, we had attained the end toward which our wishes had been so long directed.

The master of one of the canoes offered to remain on board the Pizarro as coasting pilot §. He was a Guayqueria of an excellent disposition, sagacious in his observations, and led by an unceasing curiosity to notice the productions of the sea, as well as the plants of the country. By a fortunate chance, the first Indian we met on our arrival was the man, whose acquaintance became the most useful to us in the course of our researches. I feel a pleasure in recording in this itinerary the name of Carlos del Pino, who, during the space of sixteen months, attended us in our

* Bandoulières.

† Heliconia bihai.

‡ Dasypus, *cachicamo*.

§ Practico.

course along the coasts, and into the inland country.

The captain of the corvette weighed anchor towards the evening. Before we left the shoal or *placer* of Coche, I ascertained the longitude of the east cape of the island, which I found to be 66° 11′ 53″. As we steered toward the west, we soon came in sight of the little island of Cubagua, now entirely deserted, but formerly celebrated for its fishery of pearls. There the Spaniards, immediately after the voyages of Columbus and Ojeda, founded, under the name of New Cadiz, a town, of which there now remains no vestige. At the beginning of the sixteenth century, the pearls of Cubagua were known at Seville, at Toledo, and at the great fairs of Augsburg and Bruges. New Cadiz having no water, that of the Rio Manzanares was conveyed thither from the neighbouring coast, though for some reason, I know not what, it was thought to be the cause of diseases of the eyes*. The writers of that period all speak of the riches of the first planters, and the luxury they displayed; at present, downs of shifting sand cover this uninhabited land, and the name of Cubagua is scarcely found in our charts.

Having reached these latitudes, we saw the high mountains of Cape Macanao, on the western side

* Herrera, Descrip. de las Indias occidentales (Madrid, 1730), vol. i, p. 12.

of the isle of Margaretta, which rose majestically on the horizon. If we might judge from the angles of altitude of the tops, taken at eighteen miles distance, they appeared to be about 5 or 600 toises high. According to Berthoud's time-keeper, the longitude of Cape Macanao is 66° 47′ 5″. I speak of the rocks at the extremity of this cape, and not that strip of very low land, which stretches toward the west, and loses itself in a shoal. The position of Macanao, and that which I have assigned to the east point of the island of Coche, differ only four seconds in time from the results obtained by Mr. Fidalgo.

There being little wind, the captain preferred standing off and on till day break. He was afraid to enter the port of Cumana during the night; and this prudence seemed necessary, on account of an unfortunate accident, which had lately taken place on this coast. A packet that had anchored during the night, without lighting her poop-lanterns, was taken for an enemy's ship, and was fired on from the batteries of Cumana. The captain of the packet had his leg shot off, and died a few days after at that port.

We passed a part of the night on deck. The Guayqueria pilot conversed with us on the animals and plants of his country. We learnt with great satisfaction, that a few leagues from the coast was a mountainous region inhabited by the Spaniards, in which the cold was very much felt; and that in

the plains there were two species of crocodiles, very different from each other*, boas, electric eels †, and several kinds of tigers. Though the words *bava*, *cachicamo*, and *temblador*, were entirely unknown to us, we easily guessed, from his simple description of their manners and forms, the species which the creoles meant by these denominations. Forgetting that these animals are dispersed over a vast extent of country, we hoped to find them in the forests of Cumana. Nothing so much excites the curiosity of a naturalist, as the recital of the wonders of a country where he is on the point of landing.

On the 16th of July, 1799, at the point of day, we saw a verdant coast, of picturesque aspect. The mountains of New Andalusia, half veiled by mists, bounded the horizon to the south. The city of Cumana and its castle appeared between groups of cocoa trees. We anchored in the port about nine in the morning, forty-one days after our departure from Corunna. The sick dragged themselves on deck to enjoy the sight of a land, which was about to put an end to their sufferings.

I was unwilling to interrupt the narrative of our voyage by the detail of the physical observations I made during the passage from the coasts of Spain

* Crocodilus acutus, and c. bava.

† Gymnotus electricus, temblador.

to Teneriffe, and thence to Cumana. Observations of this kind are not really interesting, except when we can dispose their results in such a manner as to lead to general ideas. The form of a personal narrative, and the nature of its composition, are not well fitted for the full explanation of phænomena, which vary with the seasons, and the position of places. In order to study the laws of these phænomena, we must exhibit them in groups, and not separately, as they were successively observed. We are under great obligations to navigators, who have accumulated an immense number of facts: but must regret, that hitherto naturalists have made so little use of their journals, which, when examined anew, may yield unexpected results. I shall insert at the end of this chapter the experiments, which I made on the temperature of the atmosphere and the ocean, with the hygrometrical state of the air, the intensity of the blue colour of the sky, and the magnetic phænomena.

TEMPERATURE OF THE AIR.

In the vast basin of the Northern Atlantic Ocean, between the coasts of Europe, Africa, and the New Continent, the temperature of the atmosphere offered us a very slow increment, as we passed from the 43d to the 10th degree of latitude. From Corunna to the Canary islands,

the centigrade thermometer, observed at noon and in the shade, ascended gradually from ten to eighteen degrees*; from Santa Cruz in Teneriffe to Cumana, the same instrument rose from eighteen to twenty-five degrees†. In the first part of the voyage, a difference of a degree of temperature corresponded to 1° 48′ of latitude; in the second part, we must traverse 2° 30′ of latitude to see the thermometer rise one degree. The maximum of the heat, which the air gradually attains two hours after the passage of the sun over the meridian, did not exceed, during this voyage, 26° 6′ (21·3° Reaumur); nevertheless we were in the month of July, and ten degrees to the south of the tropic of Cancer. The evaporation of the water, augmented by the motion of the air and of the waves, and the property which transparent liquids have‡ of absorbing very little light at their surface, contribute equally to moderate the heat in the part of the atmosphere that surrounds the equinoctial seas. It is well known, that as long as the breeze blows under the torrid zone, navigators are never exposed to violent heats.

* From the 6th to the 19th of June. See the particular observations in the journal at the end of this chapter.

† From the 25th of June to the 15th of July.

‡ The rays of light penetrate the water to considerable depths; and the first strata, by freely transmitting them, are not heated like the earth and rocks.

If we compare* the numerous observations made in the South Sea and the Atlantic Ocean during the voyages of Cook, Dixon, d'Entrecasteaux, and Krusenstern, we find, that, between the tropics, the mean temperature of the air at sea is from twenty-six to twenty-seven degrees. We must exclude from this statement the observations made during a dead calm, because the body of the vessel is then extraordinarily heated, and it is almost impossible to make a just estimation of the temperature of the atmosphere. When we look into the journals of so many celebrated navigators, we are surprised to see, that never, in either hemisphere, have they observed the thermometer under the torrid zone, in the open sea, above 34° (27·2° R). In thousands of observations made at the time of the passage of the Sun across the meridian, we scarcely find a few days when the heat has risen to thirty-one or thirty-two degrees (24·8° or 25·6° R.); while on the continents of Africa and Asia, under the same parallels, the temperature often exceeds thirty-five or thirty-six degrees. In general, between ten degrees of north and ten of south latitude, the mean heat of the atmosphere that rests on the ocean appears to me, in the low regions, from one to two degrees lower than the mean temperature of the air that surrounds the

* See an excellent memoir by Messrs. Horner and Langsdorf in the memoirs of the Academy of Petersburgh, vol. i, p. 467.

land situate between the two tropics. It is useless in this place to observe how much this circumstance modifies the climate of the whole Globe, on account of the unequal distribution of the continents at the north and south of the equator, as well as to the east and west of the meridian of Teneriffe.

The extreme slowness, with which the temperature increases during the passage from Spain to the New Continent, is highly advantageous to the health of Europeans, who go to settle in the colonies. At Vera Cruz and at Carthagena, the creoles who descend from the high savannahs of Bogota, and the central elevated plain of New Spain, are more exposed on the coasts to the attack of the yellow fever, or *vomito*, than the inhabitants of the north, who arrive by sea *. In travelling from Perote to Vera Cruz, the Mexicans descend in sixteen hours from the region of pines and oaks, from a mountainous country where the thermometer very often sinks at noon to four or five degrees, to a burning plain covered with cocoa trees, with mimosa cornigera, and other plants that vegetate only under the influence of a strong heat. These mountaineers feel a difference of temperature of eighteen degrees; and this difference produces the most fatal effects on the organs, by exciting their iritability. The European, on the

* Nouv. Esp. t. ii, p. 772.

contrary, crosses the Atlantic Ocean in thirty-five or forty days; he prepares himself gradually for the sweltering heats of Vera Cruz, which, without being the direct cause of the yellow fever, do not the less contribute to the rapidity of its progress.

A very sensible decrement of heat is observed on the Globe, whether we go from the equator to the poles, ascend from the surface of the earth into the highest regions of the air, or dive into the depth of the ocean. It is so much the more interesting to compare the rapidity of this threefold decrement, as this phænomenon has a great influence on the climatic distributions of vegetable and animal productions. The mean temperature of the lower strata of the air, which corresponds to the sixty-fifth, forty-eighth, and twentieth, degrees of north latitude, are, according to the most recent observations, 0·5°, 10·7°, and 25°; whence it results, that a centigrade degree corresponds nearly to a change of latitude of 1° 45′ *. Now the decrement of caloric is one degree every ninety toises, when we raise ourselves perpendicularly into the atmosphere †. It therefore follows, that

* In England and in Scotland it is reckoned, that a degree of Fahrenheit's thermometer corresponds to one degree of latitude. Phil. Trans. 1775, vol. lxxv, page 459. Thomson, Hist. of the Royal Soc. 1812, p. 508.

† Mr. d'Aubuisson finds only eighty-three toises to a degree for Europe in summer at eight in the morning, consequently at the period he thinks the most favourable. Journal

under the tropics, where the lowering of the temperature is very regular on mountains of considerable height, 500 toises of vertical elevation correspond to a change of latitude of 9° 45′. This result, conformable enough to those which other naturalists have adopted before me *, is very important to the geography of plants; for though in the northern countries the distribution of vegetables on the mountains and in the plains depends, like the height of the perpetual snows, more on the mean temperature of the months of summer † than

de Phys. t. lxxi, p. 38. For the torrid zone, see Observ. Astron. t. i, p. 129.

* Every hundred metres of height lower the temperature about half a degree of the common division of our thermometers : and if we take for the limit of refrigeration, that which excludes the presence of vegetation, the perpetual ice, with which the summits of mountains are loaded, will represent the perpetual ice with which the pole is covered ; and every hundred metres of vertical height will correspond to a degree of the distance from the mountain to the pole. Ramond, on the Vegetation of Mountains (Annales du Museum, t. iv, p. 396).

† Decandolle, Flore francaise, t. i, p. 1, p. 9. Leopold von Buch, Reise nach Lapland, t. ii, p. 276. Wahlenberg, Flora Laponica, 1810, p. 28. In the temperate zone it often happens, that the mean heat of a place, *a*, is less than that of a place, *b*, while the mean heat of the summer months is much greater at *a* than at *b*. It is for this reason, that a distinction is properly made between a *continental climate* and an *insular climate ;* in the first, very warm summers succeed very rigorous winters ; in the second, the contrast of the winters is less ;

on that of the whole year, the latter does not less determine in southern countries the limits, which

the summers are less warm, and the winters less cold, on account of the small changes in the temperature of the neighbouring ocean, by which the air is cooled in summer and warmed in winter. The perpetual snows descend more in Iceland than on the same parallel in the interior of Norway, and we often see, in the islands and on the coasts of western Europe, the laurel and the arbutus flourish, where the vine and the peach tree do not ripen. In the equinoctial region, on the contrary, where the difference of the seasons is as it were nothing, the geographical distribution of plants is regulated almost only according to the mean temperature of the whole year, which depends itself on the elevation of the soil above the level of the ocean. In proportion as we advance toward the north, the temperature of the months varies more and more, and the strength and richness of vegetation no longer give the measure of the mean temperature of the whole year. In Lapland, for instance, there are beautiful forests on the continent, at Enontekies, while on the island of Mageroe we scarce find a few shrubs sprinkled over the rocks; nevertheless the mean annual temperature of Enontekies is three degrees colder than that of Mageroe. The former is — 2·86°, and the latter + 0·07°. (Wahlenberg, in Gilbert's Annals, 1812, p. 271.) The more vigorous vegetation of Enontekies is the effect of a warmer summer, the mean temperature of the months of July being there 15·3°; while at the isle of Mageroe it is only, according to Mr. von Buch, 8·2°. These two places offer striking intances of the difference between a continental climate and an insular climate; or, as Mr. Wahlenberg says, between a climate of Siberia, and a climate of Iceland. In general, the problem of the climatic distribution of plants is much more complicated in the northern countries than under the tropics. In the former this distribu-

the species have not been able to pass in their distant migrations. The observation made by Tournefort on the summit of Ararat has been repeated by a great number of travellers. When we descend from a high chain of mountains, and advance toward the poles, we find at first in plains of little height, and finally in the regions near the coasts, the same arborescent plants *, which in the low latitudes cover only the heights near the perennial snows.

In estimating the rapidity with which the mean temperature of the atmosphere diminishes in proportion as we proceed from the equator to the poles, or from the surface of the earth to the high regions of the aerial ocean, I have consi-

tion depends at the same time both on the mean temperature of the summer months, and on the temperature of the soil, which differs from the mean heat of the year.

* In the study of the geographical relations of plants, we must distinguish between those vegetables, the organization of which resists great changes of temperature and barometric pressure, and those plants which appear to belong only to certain zones at certain heights. This difference is still more sensible in the temperate zone than under the tropics, where the herbaceous plants are less frequent, and where the trees are stripped of their leaves only by the effect of the dryness of the air. We see some vegetables push thir migrations from the northern coasts of Africa over the Pyrenees as far as the downs near Bordeaux, and the basin of the Loire; for instance, the merendera, the late-flowering hyacinth, and the hoop-petticoat narcissus, *narcissus bulbocodium*. Annales du Mus., t. iv, p. 401.

dered the decrement of heat as following an arithmetrical progression. This supposition is not perfectly accurate with respect to the air *; and is still less so for the water, the successive strata of which seem to diminish in temperature according to different laws at different degrees of latitude. In the interesting experiments made by Forster, Bladh, Wales, Ellis, and Peron, on the rapidity of the decrement of heat in the ocean, this decrement has been found so unequal, that a degree of the centigrade thermometer answers sometimes to twelve, at other times to twenty-four toises, and even more. We may in general admit, that the temperature decreases six times as quick in the sea as in the aerial ocean, and that it is on account of this distribution of caloric in the two elements, that plants and animals analogous to those of the polar regions find under the torrid zone, on the slope of mountains, and in the depths of the ocean, the climate which is suitable to their organization.

The same causes, to which we ought to attribute the moderate heats we feel in sailing between

* The mean temperatures augment from the equator to the poles, nearly as the square of the sine of the latitude, (Journ. de Phys., t. lxii, p. 447 ;) and the decrement of heat, in a vertical plane, follows most frequently, according to Oriani and Lindenau, the law of harmonical progression. Tables barom. p. 45. Mon. Cor. Juin 1805. Ephem. Med. 1788, p. 138.

the tropics, produce also a singular equality in the temperature of the day and the night. This equality is still greater on sea than in the interior of the continents. In the province of Cumana, in the centre of vast plains, of small height above the level of the ocean, the thermometer is generally toward sunrise four or five degrees lower than at two in the afternoon. In the Atlantic ocean, on the contrary, between eleven and seventeen degrees of latitude, the greatest variations of heat rarely exceed 1·5 or two degrees; and I have often observed, that from ten in the morning to five in the evening the thermometer did not vary 0·8 of a degree. In looking over fourteen hundred thermometrical observations made hourly during the voyage of Mr. Krusenstern, in the equatorial region of the South Sea, we see, that the temperature of the air changed from day to night only one or 1·3 centesimal degree*.

I have often endeavoured to measure the *power of the Sun* by two thermometers of mercury perfectly equal†, one of which remained exposed to the

* I constantly observed the thermometer on the deck, to windward, and in the shade. Perhaps the thermometer and barometer of Mr. Krusenstern were in a more sheltered place, for instance in the great cabin.

† This instrument had a ball of three lines diameter, which was not blackened. The scales were contained in

Sun, while the other was placed in the shade. The difference resulting from the absorption of the rays in the ball of the instrument never exceeded 3·7°. Sometimes it did not even rise higher than one or two degrees; but the heat in the body of the vessel, and the humid wind which blows by fits, render experiments of this kind very difficult. I have repeated them with more success on the ridge of the Cordilleras, and in the plains, by hourly comparing, in perfectly calm weather, the power of the Sun with its height, the blue colour of the sky, and the hygrometrical state of the air. We shall examine in another place, whether the variable differences observed between the thermometer in the Sun, and the thermometer in the shade, depend only on the greater or less extinction of light in its passage through the atmosphere.

TEMPERATURE OF THE SEA.

In my observations on the temperature of the waters of the sea, I had in view four objects very distinct from each other; the decrement of heat in the successive strata of the air; the indication of shoals by the thermometer; the temperature of the seas at their surface; and, finally, the tem-

tubes of glass very distant from the ball. Travellers prefer at present, and with reason, Mr. Leslie's photometers. Nicholson's Journal, 4to edition, vol. iii, p. 467.

perature of the currents, which, flowing from the equator * to the poles, and from the poles to the equator, form warm or cold streams† amid the motionless waters of the ocean. I shall treat here only of the heat of the sea at its surface, the phænomenon of most importance to the physical history of the Globe, because the superior stratum of the ocean is the only one, that has an immediate influence on the state of our atmosphere.

The following table is extracted from the numerous experiments contained in our journal from the 9th of June to the 15th of July.

North latitude.		West longitude.		Temperat. of the Atlantic Ocean at its surface.
39°	10′	16°	18′	15·0°
34	30	16	55	16·3
32	16	17	4	17·7
30	36	16	54	18·6
29	18	16	40	19·3
26	51	19	13	20·0
20	8	28	51	21·2
17	57	33	14	22·4
14	57	44	40	23·7
13	51	49	43	24·7
10	46	60	54	25·8

* The Gulf-stream.

† The current of Chili, which, as I have elsewhere proved, draws the waters of the high latitudes toward the equator.

From Corunna to the mouth of the Tagus, the water of the sea varied but little in its temperature; but from the thirty-ninth degree of latitude to the tenth, the increment was very sensible, and very constant, though not always uniform. From the parallel of Cape Montego to that of Salvage, the progress of the thermometer was almost as rapid as from 20° 8′ to 10° 46′; but it slackened extremely on the limits of the torrid zone, from 29° 18′ to 20° 8′. This inequality is no doubt caused by the currents, that mingle the waters of different latitudes, and which, according as we approach the Canary Islands or the coasts of Guyana, set either to the south-east or the north-north-west. Mr. de Churruca, who crossed the equator, in his voyage to the straits of Magellan, in the twenty-fifth degree of west longitude *, found the maximum of the temperature of the Atlantic Ocean at its surface in six degrees north latitude. In those parts, in latitudes equally distant from the equator, the water of the sea was colder to the south than the north. We shall soon see, that this phænomenon varies with the seasons, and that it depends in a great measure on the impetuosity, with which the waters run toward the north and north-west, across the channel formed between Brazil and the coasts of Africa. If the motion of these waters did not modify the

* In the month of October, 1788.

temperature of the ocean, the increment of heat under the torrid zone would be enormous, because the surface of the water reflects infinitely fewer of those rays which approach the perpendicular, than of those which fall in a more oblique direction.

I have observed in the Atlantic Ocean, as well as in the South Sea, that, when we change both latitude and longitude at the same time, the waters often do not change one degree of temperature, in an extent of several thousand square leagues; and that in the space comprised between the twenty-seventh degree north and the twenty-seventh south, this temperature of the seas is almost entirely independant of the variations of the atmosphere*. A very long calm, a momentary change in the duration of the currents, a tempest mingling the inferior strata of the water with the upper, may for some time produce a difference of two or even three degrees; but as soon as these accidental causes cease to act, the temperature of the ocean resumes its former stability. I shall have

* To show what little influence the air has on the temperature of the immense basin of the seas, I have added, in the journals, the indication of the heat of the atmosphere to that of the heat of the ocean. The latter may be changed by very remote causes, such as the more or less rapid melting of the polar ice, or winds blowing in other latitudes, and producing currents.

occasion to return to this phenomenon, one of the most invariable that nature offers.

I have constructed a chart of the temperature of the seas, as well from my own observations, made from the forty-fourth degree of north to the twelfth degree of south latitude, and from the forty-third to the hundred and fifth of west longitude, as from a great number of materials, which I have with some difficulty collected. As a considerable body of water cools with extreme slowness, it is sufficient to plunge the thermometer into a bucket of water just taken from the surface of the ocean. Though this experiment is very simple, it has been hitherto singularly neglected. In the greater part of the narrations of voyages, the temperature of the ocean is but casually mentioned; for instance, on occasion of the researches made on the cold that prevails at great depths, or on the stream of warm water that traverses the Atlantic. I have not been able to make use of the excellent work of Mr. Kirwan *on climates*, because this celebrated naturalist has not sufficiently distinguished, in his tables of the temperature of the different latitudes, between what is the result of direct experiments, and what of theory: but the second voyage to the straits of Magellan*, under the command of Churruca and Galeano,

* Don Cosme de Churruca, Apendice del Viage al Magellanés 1793, p. 98.

the relation of Abbé Chappe's Voyage to California, the work published at Philadelphia under the title of Thermometrical Navigation*, and particularly the interesting experiments made in 1800 by Mr. Perrins, on board the Skelton, in the course of a voyage from London to Bombay, have furnished me with numerous materials for my work. Employed at Lima in researches on the temperature of the sea, I had engaged an officer of the royal navy, Mr. Quevedo, to observe day by day, during his passage from Peru to Spain, round Cape Horn, the heights of two thermometers, one of which should be exposed to the air, and the other plunged into the upper stratum of the ocean. The observations made by Mr. Quevedo in 1802†, on board the frigate Santa Rufina, which will be given in this work, embrace both temperatures, from the sixth degree of south to the thirty-sixth of north latitude; and are so much the more valuable, as this very well informed navigator knew perfectly his longitude by means of a chronometer by Brockbanks, and of the distances of the moon from the sun. His meteorological instruments, constructed by Nairne, had been compared, before his departure, with those I made use of on the Cordilleras.

From the equator to the twenty-fifth and twen-

* Thermometrical Navigation, 1799, p. 37.

† Nicholson's Journal, 1804, p. 131.

ty-eighth degrees of north latitude, the temperature is remarkably constant, notwithstanding the difference of the meridians: it is more variable in the high latitudes, where the melting of the polar ice, the currents caused by this melting, and the extreme obliquity of the solar rays in winter, diminish the heat of the ocean. The following table, which contains experiments taken without discrimination from several nautical journals, confirms these assertions. The fractions of degrees, by which the results are expressed, arise from the reduction of the scales of the thermometer of Reaumur or Fahrenheit to the centigrade division.

TABLE *of the*

Temperature of the Atlantic Ocean in different degrees of longitude.

Latitude.	Longitude.	Temperature of the ocean	Period of the observation.	Observers.	Mean temperature of the air in the basin of the seas.
0° 58′ S.	27° 34′ W.	27·2°	Nov. 1788	Churruca	27° (Cook).
0 57 S.	30 11 W.	27·7	April 1803	Quevedo	
0 33 S.	21 20 W.	27·7	March 1800	Perrins	
0 11 N.	84 15 W.	28·0	Febr. 1803	Humboldt	
0 13 N.	51 42 E.	27·1	May 1800	Perrins	
25° 15′ N.	20° 36′ W.	20·0°	June 1799	Humboldt	21° (La Perouse and Dalrymple)
25 29 N.	39 54 W.	21·6	April 1803	Quevedo	
25 49 N.	26 20 W.	20·7	March 1800	Perrins	
27 40 N.	17 4 W.	21·6	Jan. 1768	Chappe	
28 47 N.	18 17 W.	23·5	Octob. 1788	Churruca	
42° 34′ N.	15° 45′ W.	11·1°	Febr. 1800	Perrins	12·7° (Cook and d'Entrecasteaux).
43 17 N.	31 27 W.	15·5	May 1803	Quevedo	
43 58 N.	13 7 W.	15·9	June 1799	Humboldt	
44 58 N.	34 47 W.	12·7	Dec. 1789	Williams	
45 13 N.	4 40 W.	15·5	Nov. 1776	Franklin	
48 11 N.	14 18 W.	14·3	June 1790	Williams	

It is very remarkable, that, notwithstanding the immensity of the ocean, and the rapidity of the currents, there is a great uniformity every where in the maximum of heat in the equinoctial seas. Mr. Churruca found this maximum, in 1788, in the Atlantic Ocean, at 28·7°; Mr. Perrins, in 1804, at 28·2°; Mr. Rodman*, in his voyage from Philadelphia to Batavia, at 28·8°; and Mr. Quevedo, at 28·6°. In the South Sea I observed it the same year at 29·3°: consequently, the differences scarcely exceed 1° of the centigrade thermometer, or $\frac{1}{28}$ of the total heat. We must recollect, that, under the temperate zone, to the north of the parallel of 45°, the mean temperatures of different years vary more than 2°, or a fifth of the quantity of caloric that a determinate part of the Globe† receives.

* Coxe, Philadelphian Medical Museum, vol. 1, p. 83.

† Geneva from 1796 to 1809: 7·87°; 8·34°; 8°; 7·47°; 8·38°; 8·49°; 8·49°; 8·27°; 8·5°; 7·12°; 8·73°; 7·78°; 6·68°; and 7·54° of Reaumur's thermometer: Paris, at the Observatory, from 1803 to 1810; 11·95°; 10·75°; 10·35°; 10·55°; 10·50°; 10·65°; 11·10°; and 9·79° of the centigrade thermometer. In proportion as we approach the tropics, the variations of the annual temperature diminish. Rome (lat. 41° 53′) from 1789 to 1792; 13·6°; 12·5°; 13·4°; and 12·9°, Reaum. (Buch, in Gilbert's Annalen der Physik, t. 24, p. 238). Philadelphia, (lat. 39° 56′) from 1797 to 1803. 12·7°; 11·6°; 11·8°; 11·7°; 12·7°; and 12·8° of the centigrade thermometer. From these very accurate observations it results, that the extremes at Geneva have been 2·5°; at Paris 2·2°;

The maximum of the temperature of the seas, which is from 28 to 29 degrees, proves more than any other consideration, that the ocean is in general warmer than the atmosphere with which it is immediately in contact, and of which the mean temperature, near the equator, is from 26 to 27 degrees. An equilibrium between the two elements cannot be established; not only on account of the winds, which carry the air near the poles toward the equator, but also in consequence of the absorption of caloric, the effect of evaporation. It is so much the more extraordinary to see the mean temperature rise, in a part of the equatorial ocean, beyond 29° (23·2° R.); as even on the continents, amidst the most arid sands, we scarcely know a place, where the mean heat of the year reaches to 31°.

It remains to be examined, whether in the low latitudes, in the same parallels, we find, in different seasons, nearly the same temperatures. The following table will facilitate this kind of research.

at Rome, 1·3°; and at Philadelphia, 1·1° of the centesimal division. The variations observed in the temperature of the sea at its surface seemed to extend, under the temperate zone, between the 35th and 45th degrees of latitude, to three degrees above and below its mean temperature; and I was wrong in saying, in a general manner, in the introduction to Thomson's Chemistry (French translation, t. i, p. 100), that the ocean every where directly indicates the mean temperatures of the air corresponding to the different latitudes.

TABLE

Of the Temperature of the Atlantic Ocean in different seasons.

North Latitude.	Centigrade Thermometer and West Longitude.					
	Chappe, Jan. and Feb. 1768.	Perrins, March 1804.	Quevedo, April and May, 1803.	Humboldt, June and July, 1799	Churruca, October, 1788.	Rodman, Oct. and Nov. 1803.
$34\frac{1}{2}$	. . . . .	Th. 16°	Th. 8·8°	Th. 16·5°	Th. 23·4°	Th. 24·3°
	. . . . .	Lg. 18° 20′	Lg. 41° 11′	Lg. 16° 55′	Lg. 10° 37′	Lg. 52° 40′
30°	Th. 20·7°	Th. 19·3°	Th. 20·7°	Th. 18·4°	Th. 23·8°	. . . .
	Lg. 9° 30′	Lg. 23° 15′	Lg. 38° 40′	Lg. 16° 50′	Lg. 16° 4′	. . . .
26°	Th. 23·9°	Th. 20·7°	Th. 21·2°	Th. 20·2°	. . . .	Th. 25·0°
	Lg. 18° 10′	Lg. 26° 20′	Lg. 39° 51′	Lg. 19° 45′	. . . .	Lg. 35° 20′
18°	. . . . .	Th. 22·7°	Th. 23·2°	Th. 22·4°	Th. 26·4°	Th. 26·2°
	. . . . .	Lg. 28° 32′	Lg. 41° 7′	Lg. 32° 10′	Lg. 22° 10′	Lg. 29° 50′
10°	. . . . .	Th. 23·8°	Th. 26·2°	Th. 25·8°	Th. 28·2°	Th. 28·2°
	. . . . .	Lg. 24° 30′	Lg. 37° 7′	Lg. 65° 40′	Lg. 22° 25′	Lg. 26° 50′

TABLE of the Temperature of the Atlantic Ocean, &c. *continued.*

North Latitude.	Centigrade Thermometer and West Longitude.					
	Chappe, Jan. and Fob. 1768.	Perrins, March 1804.	Quevedo, April and May, 1803.	Humboldt, June and July, 1799.	Churruca, October, 1788	Rodman, Oct. and Nov. 1803.
5°	. . . .	Th. 26·5° Lg. 22° 33′	Th. 26·5° Lg. 33° 10′	. . . .	Th. 28·3° Lg. 22° 27′	Th. 28·8° Lg. 25° 10′
Maximum of the temperature of the Ocean.	. . . .	Th. 28·2°, in 0° 15′ of north lat. and 22° 21′ of west long.	Th. 28·6°, in 2° 2′ of south lat. and 29° 40′ of west long.	. . . .	Th. 28·7° in 6° 15′ of north lat. and 22° 12′ of west. long.	Th. 28·8° from 8° 40′ to 5° 45′ of north lat. and from 25° 50′ to 25° 0′ of west long.

A great mass of water follows with extreme slowness the changes of temperature observed in the atmosphere, and the maximum of the mean temperatures of each month does not occur at the same time in the ocean and in the air. The increment of the heat of the seas necessarily undergoes a delay; and as the temperature of the air begins to diminish, before that of the water has reached its maximum, it follows, that the extent of the thermometrical variations is smaller at the surface of the sea than in the atmosphere. We are still very far from knowing the laws of these phænomena, which have a great influence in the economy of nature.

Mr. Kirwan admits, that between the eighteenth degree of north and the eighteenth of south latitude, the mean temperatures of the months differ only five centesimal degrees, and this estimation is somewhat too low; for we know by observations, carefully calculated, that at Pondicherry, at Manilla, and in several other places between the tropics, the mean heats of the months of January and August differ eight or ten degrees. Now the variations of the air are at least a third less in the basin of the seas than on the continent; and the ocean undergoes a part only of the changes of temperature of the atmosphere that surrounds it. Hence it results, that, if the equinoctial oceans did not communicate with the seas of the temperate

zones, the local influence of the seasons would be almost nothing in it.

M. Peron *, who has very successfully repeated the experiments made by Ellis, Forster, and Irvine, on the cold that prevails at the bottom of the ocean, affirms, "that every where the open sea is colder at noon, and warmer at night, than the surrounding air." This assertion has need of much restriction; I am ignorant whether it be exact in the forty-fourth and forty-ninth degrees of south latitude, where this laborious naturalist appears to have made the greatest number of his thermometrical observations; but between the tropics, where the air in the open sea is scarcely two or three degrees colder at midnight than two hours after the culmination of the Sun, I have never found the least change in the temperature of the ocean, either day or night. This difference is sensible only in a dead calm, during which the surface of the water absorbs a greater mass of rays; but we have already observed, that the thermometrical experiments made in this state of the ocean relate to a local phenomenon only, and ought to be entirely excluded in discussing a problem of general physics.

The observations contained in the preceding tables have all been collected under the same

* Annales du Museum, t. v. p. 123—148. Journ. de Phys. t. lix, p. 361. Gilbert, Annalen der Physik, t. xix, p. 427.

parallels, but in very different longitudes and seasons. At the time of the voyage to the Magellanick regions, and to Batavia, the *maximum* of the temperature was found much more to the north than it had been perceived in all the other voyages; which has had a sensible influence on the heat of the sea to the north of the tropic of Cancer. The *maximum*, according to Churruca and Rodman, was in October, in six degrees north; according to Mr. Quevedo, in March, in 20° 2′ south; and according to Dr. Perrins, in April, in 0° 15′ north. I observed it in March, at the east of the Galipago islands, in 2° 27′ of north latitude. It is probable, that changes in the currents cause these extraordinary anomalies; and that the great circle, which passes through the points where the water of the sea is the warmest, cuts the equator at an angle which is variable according as the declination of the Sun is north or south. These phænomena, connected perhaps with those of the limit of the trade winds, and the *maximum* of the saltness of the sea, deserve to be carefully examined; but we should not be surprised at a failure of accurate observations on the temperature of the equatorial seas, if we recollect, that we are still ignorant of the thermometrical variations in the neighbouring seas of Europe *.

* Since my return in 1804, I have in vain exhorted those naturalists, who inhabit the coasts of the ocean, in Spain, in

From the thirtieth degree of north latitude, the results which I attained agree very well with the observations of Perrins and Quevedo. It is not probably to the local influence of the seasons, as we have just proved, but to the motion of the waters, and to remote causes, that we must attribute the extent of the variations of temperature observed between the tropics in the voyage from London to Bombay. These variations have risen to five degrees, while in the South Sea I found them only 2·7°. Quevedo, in traversing from south to north a space of six hundred and forty leagues, saw the heat of the Atlantic ocean from the tropic of Capricorn to the ninth degree of

France, and in England, to ascertain, for each month in the year, the mean temperature of the sea at its surface, compared with the mean temperature of the air on the neighbouring coasts. What has been published on this subject is founded either on theoretical considerations, or on a small number of experiments, which have not been made in the open sea, but in harbours and sheltered roads. What is the maximum of cold, which the ocean attains in the forty fifth degree of latitude, taking the mean average of several days? to what month does this maximum correspond? It is asserted that, near Marseilles, the sea is never colder than 6·5°, or warmer than 25°; though the extremes of the temperature of the air are often — 4° and + 35° (Mém. de la Soc. Royal de Med. 1778, p. 70). Can it be admitted, that, in the open sea, the heat of the Atlantic rises to 20° in latitude 45°?

north latitude, change only 1·7° ; and as far as the twenty-third of north latitude, the greatest variation of the sea extended no farther than 3·7°.

This great regularity in the distribution of the heat of the ocean is manifested also in a very sensible manner, when we compare, in the two hemispheres, zones equally distant from the equator.

TABLE.

Comparison of the Temperature of the Seas in both Hemispheres.

Latitude.	Longitude.	Period of the Observation.	Temp. of the Ocean at its surface. (Cent. Th.)	Names of the Observers.	Mean temp. of the air observed on the Continents.	Remarks. (The temperat. of the Ocean is nearly equal to the mean atmosph. temp of the *month*; the temp. of the air expresses the mean heat of the *year* under different parallels.)
3° 53′ N.	90° 36′ W.	February . 1803	28·7°	Humboldt	27° to 28°	South Sea.
3 16 S.	86 23 W.	January . 1803	27·0	*Idem* . .		
4 8 N.	22 54 W.	October . 1788	27·5	Churruca	. . . . .	Atlantic Ocean.
3 44 S.	28 10 W.	November 1788	27·0	*Idem* . .		
4 36 N.	53 50 E.	May . . 1800	27·6	Perrins .	. . . . .	Indian Sea.
4 44 S.	24 51 W.	April . . 1800	26·4	*Idem* . .		Atlantic Ocean.
11 12 N.	37 41 W.	April . . 1803	27·1	Quevedo .	. . . . .	Atlantic Ocean.
11 32 S.	29 41 W.	March . 1803	27·0	*Idem* . .		
11 58 N.	25 26 W.	March . 1800	23·2	Perrins .	25·8°	Atlantic Ocean.
12 50 S.	27 20 W.	April . . 1800	25·8	*Idem* . .		

Latitude.	Longitude.	Period of the Observation.	Temp. of the Ocean at its surface. (Cent. Th.)	Names of the Observers.	Mean temp. of the air observed on the Continents.	Remarks. (The temperat of the Ocean is nearly equal to the mean atmospheric temp. of the *month*; the temp. of the air expresses the mean heat of the *year* under different parallels.)
15° 24′ N.	39° 44′ W.	April . . 1803	23·8°	Quevedo .	. . . .	Atlantic Ocean.
15 50 S.	30 34 W.	March . 1803	26·5	*Idem* . .		
23 0 N.	26 50 W.	March . 1800	21·0	Perrins .	23°	Atlantic Ocean.
23 40 N.	41 6 W.	April . . 1803	22 1	Quevedo .		
22 52 N.	22 13 W.	June . . 1799	20 0	Humboldt		
23 23 S.	28 58 W.	March . 1803	27 0	Quevedo .		
23 23 S.	29 40 W.	April . . 1800	25·5	Perrins .		
23 30 S.	50 10 E.	May . . 1800	22·0	*Idem* . .	. . . .	Indian Sea.
31 0 N.	79 37 W.	May . . 1804	21·5	Humboldt	21·6	Atlantic Ocean.
31 22 N.	15 7 W.	October 1788	23·6	Churruca		
31 58 N.	20 10 W.	March . 1800	17·7	Perrins .		
31 30 N.	38 45 W.	April . . 1803	20·7	Quevedo .		
31 34 S.	28 29 W.	March . 1803	24·3	*Idem* . .		
31 0 S.	26 20 W.	April . . 1800	20·5	Perrins .		
31 34 S.	46 56 W.	November 1788	20·5	Churruca		
31 4 S.	47 40 E.	May . . 1800	19·4	Perrins .	. . . .	Indian Sea.

Latitude.	Longitude.	Period of the Observation.	Temp. of the Ocean at its surface. (Cent. Th.)	Names of the Observers	Mean temp. of the air observ d on the Continents.	Remarks. (The temperat. of the Ocean is nearly equal to the mean atmospheric temp. of the *month*; the temp. of the air expresses the mean heat of the *year* under different parallels)
30° 38′ N.	41° 2′ W.	May . . 1803	19·3°	Quevedo .		
36 5 N.	76 41 W.	May . . 1803	20·0	Humboldt		
36 4 N.	17 5 W.	June . . 1799	15·2	*Idem* . .		
33 16 N.	10 24 W.	October 1788	23·4	Churruca	19·8°	Atlantic Ocean
35 22 S.	50 32 W.	November 1788	17·0	*Idem* . .		
36 3 S.	17 6 W.	April . . 1800	18·8	Perrins .		
36 5 S.	41 58 W.	May . . 1803	20·0	Quevedo .		
33 52 S.	94 52 W.	February 1803	22·0	*Idem* . .	. . . .	South Sea.
40 28 N.	33 35 W.	May . . 1803	17·1	Quevedo .		
40 30 N.	68 36 W.	July . . 1804	18·7	Humboldt		
42 34 N.	15 45 W.	February 1800	1[illegible]·2	Perrins .	17·5	Atlantic Ocean.
42 30 S.	50 30 W.	March . . 1803	13·2	Quevedo .		
40 36 S.	48 20 W.	March . 1803	15·5	*Idem* . .		
40 48 S.	93 56 W.	February 1803	17·0	*Idem* . .	. . . .	South Sea.

In discussing these observations made at different seasons, we should compare the months, which in both hemispheres are almost equally distant from the solstices. It is necessary also to pay attention to the slowness, with which, in the temperate zone, the sea receives and loses the heat communicated to it by the air. The anomalies that take place proceed perhaps in part from the variations, which the mean atmospherical temperatures of the months undergo on the same spot, but in different years.

The preceding table shows, that the ideas which are generally formed of the low temperature of the southern hemisphere are not perfectly accurate. Near the poles, and in very high latitudes, the cold of the seas is undoubtedly less to the north than the south of the equator; but this difference is not sensible between the tropics; it is even very little perceptible as far as the 35th and 40th degrees of latitude.

Mr. Kirwan obtained an analogous result for the air that rests on the ocean, by taking the averages of a great number of observations made during the winter and summer in each hemisphere, and recorded in the journals of navigators*. From the equator to the thirty-fourth degree of South

* See a very interesting paper by him in the Transactions of the Irish Academy, vol. viii, p. 422.

latitude, the winters are more temperate than under the same parallels in the Northern Hemisphere; and even in fifty-one degrees South, at the Falkland Islands, the month of July is much less cold than the month of January at London.

TABLE.

Comparison of the temperature of the air in both hemispheres.*

Latitude.	Correspondent months.	Mean temp. of the months. Southern hemisphere.	Northern hemisphere.
0°—15°	December . .	28·0°	. . .
	June . . .	. . .	28·5
18	October . .	. . .	26·5
	April . . .	27·5	. . .
2°—26	January . .	. . .	19·3
	July . . .	22·5	. . .
	September . .	. . .	20·5
	March . . .	20·8	. . .
34	December . .	. . .	15·4
	June . . .	13·8	. . .
	February . .	. . .	17·0
	August . .	16·8	. . .
43	July . . .	. . .	18·2
	January . .	15·2	. . .
48	June . . .	. . .	17·7
	December . .	7	. . .
58	July . .	. . .	13·5
	January . .	6.2	. . .

* The observations employed in constructing this table

These investigations are highly interesting to the physical history of our planet. Does the quantity of free caloric remain the same during thousands of years? have the mean temperatures corresponding to different parallels augmented, or diminished, since the last revolution that altered the surface of the Globe? We cannot answer these questions in the present state of our knowledge; we are ignorant of every thing that relates to a general change of the climates, as we know not whether the barometric pressure of the atmosphere, the quantity of oxygen, the intensity of the magnetic powers, and a great number of other phænomena, have undergone any change since the time of Noah, of Xisuthris, or Menou. As a local variation in the temperature of the ocean at its surface might be the effect of a progressive change in the direction of the currents, which bring hotter or colder water, according as they come from lower or higher latitudes; so, in a very limited extent of sea, a similar refrigeration might be produced by the conflict of oblique and submarine currents, which mix the waters of the bottom with those at the surface; but we can draw no general conclusions from changes that have taken place on a few points of the

were all made at sea, except those, from which the mean temperature for the latitude of 34° was deduced. For these we are indebted to Mr. Sparmann, during his stay at the Cape of Good Hope.

Globe, whether at the surface of the sea, or on the continent*. It is only by the comparison of a great number of observations, made in different parallels of latitude, and at different degrees of longitude, that we shall be able to solve the important problem of the increase or diminution of the heat of the Earth.

As a preparation for this work, we must carefully determine, at a given period, the *maximum* of the temperature of the waters of the sea under the tropics, and in the *parallel of the warmest waters*. We have proved, that this maximum is at present, in places the most remote from each other, from 28° to 29° of the centigrade thermometer. Very distant posterity will one day decide, whether, as Mr. Leslie † has endeavoured to prove by ingenious hypotheses, two thousand four hundred years are sufficient to augment the mean temperature of the atmosphere a single degree. However slow this increment may be, we must admit, that an hypo-

* The currents of the aerial ocean act like the currents of the sea. In Europe, for instance, the mean temperature of a place may augment, because very remote causes make a change in the equilibrium between the winds of the south-west and those of the north-east. We may even conceive a partial change in the mean barometric height of a place, without this phænomenon indicating any general revolution in the constitution of the atmosphere.

† An experimental Inquiry into the Nature and Propagation of Heat, 1804, p. 181, and 536.

thesis, according to which organic life seems gradually to augment on the Globe, occupies more agreeably our imagination, than the old system of the cooling of our planet, and the accumulation of the polar ice. Some parts of physics and geology are merely conjectural; and it might be said, that science would lose much of its attraction, if we endeavoured to confine this conjectural part within too narrow limits.

HYGROMETRICAL STATE OF THE AIR.

Notwithstanding the doubts which have been raised in these latter times respecting the accuracy, with which hair or whalebone hygrometers indicate the quantity of vapours mingled in the atmospheric air, it must be admitted, that, even in the present state of our knowledge, these instruments are highly interesting to a naturalist, who can transport them from the temperate to the torrid zone, from the northern to the southern hemisphere, from the low regions of the air that rest on the sea to the snowy tops of the Cordilleras. I would rather, says M. de Saussure *, that the most imperfect instrument were made use of, a hempen string with a stone suspended to it, than entirely neglect researches, for which so little has been done in distant voyages †. Without entering into the

* Essai sur l'Hygrométrie, §. 353.

† M. Peron thinks, " that it was in the voyage of Captain

question, whether inaccurate experiments are more injurious to the progress of the sciences than the total ignorance of a certain number of facts, I may affirm, that several hygrometers, constructed by Mr. Paul at Geneva, and reduced from time to time to the point of extreme humidity *, have furnished me with observations, which accorded very well with each other. I have always pre-

Baudin, that hygrometers for the first time crossed the ocean." But before this voyage, and even a long time before my own, hygrometrical observations had been made in the voyage of Lapérouse, and at Bengal by the son of Mr. Deluc.

* I made this correction every time that I had any doubt of the indication of the hygrometer. I employed immersion in rain water, as Mr. Deluc recommends for whalebone. It is known, that this method of verification, even with hair, can cause but a slight error of 1° or 1·5° (Essai, §. 32, p. 37); while the best hygrometers often differ from each other two degrees. I have never been able to reduce the hair or whalebone to the degree of extreme siccity, for want of a portable apparatus, which I regret not having made before my departure. I advise travellers to provide themselves with a narrow jar, containing caustic potash, quicklime, or muriat of lime, and closed with a screw by a plate on which the hygrometer may be fixed. This small apparatus would be of easy conveyance, if care were taken to keep it always in a perpendicular position. As under the tropics Saussure's hygrometer generally keeps above 85°, a frequent verification of the single point of extreme humidity is most commonly sufficient to give confidence to the observer. Besides, in order to know on which side the error lies, we should recollect, that old hygrometers, if not corrected, have a tendency to indicate too great dryness.

ferred the old instrument with a single hair to that of Richer, in which several hairs act at the same time on the index, and with unequal tensions. I can affirm also, that every thing Mr. de Saussure has advanced, in his Essay on Hygrometry, of the long duration of his portable hygrometers, is extremely exact *. I have preserved some without any alteration during three years travels in the forests and mountains of South America. Before my departure they were compared by Mr. Pictet with the hygrometers of the observatory at Geneva; and I have almost always found them at 99° or 100·5°, when I have been able to expose them to a very thick fog.

As the fiftieth degree of the whalebone hygrometer corresponds to the eighty-sixth degree of the hair hyrometer, I made use of the first at sea and in the plains, while the second was generally reserved for the dry air of the Cordilleras. The hair below the sixty-fifth degree of Saussure's instrument indicates, by great variations, the smallest changes of dryness; and has besides the advantage of putting itself more rapidly into a state of equilibrium with the ambient air. Deluc's hygrometer acts, on the contrary, with extreme slowness; and on the summit of mountains, as I have frequently experienced to my great regret, we are often uncertain whether we have not ceased our observa-

* Ibid, §. 67.

tions before the instrument has ceased its movement. On the other hand, this hygrometer, furnished with a spring, has the advantages of being strong, marking with great exactness in very moist air the least increment of the quantity of vapour in solution, and acting in all positions; while Saussure's hygrometer must be suspended, and is often deranged by the wind, which raises the counterpoise of the index. I have thought it might prove useful to travellers, to mention in this place the results of an experience of several years.

During the whole of the passage, the apparent humidity of the atmosphere, that indicated by the hygrometer not corrected by the temperature, augmented sensibly, notwithstanding the progressive increment of the heat. In the month of July, in the thirteenth and fourteenth degrees of latitude, Saussure's hygrometer marked at sea from eighty-eight to ninety-two degrees *, in perfectly serene weather, the thermometer being at twenty-four degrees. On the banks of the lake of Geneva †,

* The hair hygrometer being much better known than that of whalebone, in order to preserve a uniform rate, the hygrometrical results have been given according to Saussure's instrument, even when the observations were made with that of Deluc. It is only in the metereological journal, that the hygrometer employed for each series of experiments is mentioned. The numbers always mark the apparent humidity, if the contrary be not expressly stated.

† Under the temperate zone, on the continent, the extremes

the mean humidity of the same month is only eighty degrees, the average heat being nineteen degrees. Now, on reducing these hygrometrical observations to a uniform temperature, we find, that the real humidity, in the equinoctial basin of the Atlantic Ocean, is to the humidity of the months of summer, at Geneva, in the ratio of twelve to seven. This enormous humidity of the atmosphere explains in a great measure the strength of vegetation, which we admire on the coasts of South America, where no rain falls for several years.

As the quantity of vapours changes, not with the elasticity of the air, but with the temperature, we may compare, either the absolute quantities of vapour contained in the atmosphere in two places, or the proportion of their quantities to those necessary to the complete saturation of the air in different climates. We know by very accurate experiments the capacities of saturation of the air at different degrees of the thermometer; but the relations which exist between the progressive lengthening of a hygroscopical body, and the quantities of vapour contained in a given space, have not been appreciated with the same degree of certainty. These considerations have induced me to publish

were commonly in summer sixty-seven and eighty-eight degrees, the temperature of the air being from twenty-six to eighteen centesimal degrees.

the indications of the hair and whalebone hygrometers just as they were observed, marking the degree shown by the thermometers connected with these two instruments. To facilitate to a certain point the comparison of the observations made in different latitudes, I shall here insert a table, which was calculated by M. d'Aubuisson, when he made his valuable researches on the coefficients of the barometric formulas. The whole of the results prove, that as we advance towards the equator, the air approaches the point of saturation. We have chosen the periods, when the temperature of the sea was nearly equal to that of the air. Of eight columns, which compose this table, the first contains the time of the observation; the second the latitude of the place; the third the state of the thermometer; the fourth the state of the hygrometer; the fifth the weight of vapour contained in a cubic metre of air, supposing it saturated; the sixth the weight of vapour contained in a cubic metre of air, at the degree of the hygrometer observed; the seventh, the thickness of the sheet of water which should be evaporated in an hour's time, if the surrounding air was perfectly dry; the eighth the same thickness, admitting in the air the quantity of vapor indicated by the hygrometer *.

* The following is the basis of Mr. d'Aubuisson's calculation;

t = the height of the centigrade thermometer.

h = the height of de Saussure's hygrometer.

Let $\left.\begin{array}{l} a = \\ b = \\ c = \\ d = \end{array}\right\}$ the quantities indicated in the columns of the following table, and designated by the same letters.

$\varphi =$ Elastic force of the vapour in a space which is saturated.

According to the observations of Saussure, it is found, that the elastic force, in a space in which the hygrometer marks μ degrees is $\varphi\ (0{\cdot}015\ \mu - 0{\cdot}47)$, while $\mu > 50°$. Let $0{\cdot}015\ \mu - 0{\cdot}47 = m$.

Mr. La Place gives, from the experiments of Dalton,

$$\varphi = \overset{\text{mèt.}}{0{\cdot}005123} \times (10)^{t.0{\cdot}0279712 - + {}^{2}0{\cdot}000062583.}$$

(*Méc. cél.* t. iv, p. 273.) Hence it is concluded:

$$a = \varphi \frac{1221{\cdot}8}{1 + t.\ 0{\cdot}00375};\ b = a \times m;\ c = \varphi\ \overset{\text{millim.}}{42};\ \text{and } d = c$$

$(1 - m)$.

TABLE.

Results of the Hygrometrical Observations made in the basin of the Atlantic Ocean.

Periods of the observation.	Latitude of the place in the open sea.	Data.		Quantity of vapor contained in the air.		Quantity of water evaporated in an hour's time.	
		Therm.	Hygrom.	to saturation a) grammes	in reality. b) grammes.	the air being dry. c) millim.	in reality. d) millim.
9 June 1799	39° 10′	14·5°	82°	14·6	11·4	0·53	0·13
15	30 36	20·0	85·7	20·0	16·2	0·74	0·14
16	29 18	20·0	83·8	20·0	15·7	0·74	0·16
30	18 53	21·2	81·5	21·3	16·0	0·79	0·20
4 July .	16 19	22·5	88	22·9	19·4	0·85	0·13
10	12 34	24·0	89	24·8	21·5	0·93	0·13
12	10 46	25·4	90	26·7	23·5	1·01	0·12
14	11 1	25	92	26·8	23·8	0·98	0·09

It follows from these researches, that, if the quantity of vapor, which the air commonly contains in our middle latitudes, amounts to about three quarters of the quantity necessary for its saturation, in the torrid zone this quantity is raised to nine tenths. The exact ratio is from 0·78 to 0·88. It is this great humidity of the air, under the tropics, which is the cause that the evaporation is less than we should have supposed it to be from the elevation of the temperature.

I was often surprised, during this passage, and at a later period in the vast basin of the Pacific Ocean, at not seeing the hygrometer make nearer approaches to the point of extreme humidity. This instrument has been sometimes, far from the coasts, at eighty-three degrees; and generally in the equinoctial zone, it kept between ninety and ninety-two degrees. According to the meteorological tables, published by Messrs. Langsdorff and Horner, we see, that, in Krusenstern's voyage, as well as in that of La Perouse, the apparent humidity* was found to be from eighty eight to ninety two degrees. The extremes were eighty three and ninety seven degrees, which is conform-

* Mém. de l'Acad. de Pétersbourg, t. i, p. 454. I have corrected the indications of Deluc's hygrometer, which was used by the Russian navigators. In their instrument the 76th degree corresponded to the point of extreme humidity. Lamanon's hygrometers were well verified, since they indicated 100 or 101 degrees in a thick fog. Voyage de La Pérouse, t. iv, p. 261.

able to my observations. It is true, that, from the curious researches of M. Gay-Lussac, the hygrometer can never indicate beyond ninety degrees in air in contact with a saturated solution of muriat of soda; but the water of the sea is every where so distant from the point of saturation, that the salt which it contains would scarcely change a single degree the point of the greatest humidity, that the lower strata of the air in the basin of the seas might attain. This point would be indicated by the hygrometer, if the tranquillity of the atmosphere were not troubled by currents.

The wind, in displacing the particles of the air, does not make the hair rise to dry, as it causes the descent of a thermometer exposed to the sun by carrying off the strata of air strongly heated. Numerous experiments* of M. de Saussure prove, that the air acts in the same manner on hygroscopic substances, whether it be in motion or at rest; consequently the influence of horizontal or descending winds becomes sensible to the hygrometer inasmuch only as these winds bring strata of air less loaded with vapors. If oblique currents are established, either by a sudden acceleration in the decrement of caloric, or by the conflict of several winds, or by electric phenomena, the upper strata of the atmosphere are mingled with the lower strata. These movements, joined to the horizontal winds that traverse great conti-

* Essai sur l'Hygrométrie, § 150—156.

nents before they reach the basis of the seas, perpetually tend to remove the hygrometer from the extreme point of saturation. Perhaps also the polar currents, which, from the effects of the rotation of the Globe, seem to produce the appearance of trade winds, have too much velocity to suffer the air they bring, to load itself under each parallel with the whole quantity of vapor correspondent to its temperature.

Naturalists, who have long marked the progress of the hygrometer in the open air, have seldom seen these instruments at a hundred degrees, except in a thick fog. In the heaviest rain, even in the midst of the clouds, the hair hygrometer often keeps at ninety and ninety five degrees*. In this case the air placed between the drops of water, or the vesicular vapor, is far from being saturated; and I doubt whether the atmosphere, preserving a perfect transparency,

* M. de Saussure observed it once at 84·7° during a very heavy shower. Essai, § 326, p. 321. On the other hand, Mr. Deluc found, that his hygrometers, which, plunged into water, marked 100, kept at 83 3° when they were placed under a glass jar filled with atmospheric air, and of which the sides were constantly moistened. On seeing in my journal, that Deluc's hygrometer kept oftenest between sixty and sixty three degrees, it should be remembered, that in this instrument the point of saturation *in the air* is not a hundred, but about eighty-four or eighty-five degrees. Idées sur la Météorologie, 1786, t. i, p. 72; t. ii, p. 473. Urenna, Anales de Historia natural, 1803, p. 229.

ever attains the maximum of humidity, which we obtain under our glass jars. M. de Saussure, after having explained the long series of his manometrical and hygrometrical experiments, made at different degrees of temperature, admits, that the last degrees of his instrument are perhaps only *degrees of supersaturation*, and that the quantity of vapor that a certain volume of free air can contain, is probably less than might be admitted from the experiments made in our laboratories*.

The naturalists, who accompanied the Chevalier Krusenstern in his voyage round the world, assert, that Deluc's hygrometer enabled the mariners to foresee stormy weather, during the passage from Washington Islands to Sangasacky; and in all other parts of the torrid zone, where the changes of the atmosphere have scarcely any influence on the barometer. Mr. Peron, on the other hand, says, that he has seen the barometer constantly fall at sea, when the hair hygrometer advanced toward extreme humidity. I have had no opportunity of verifying either of these assertions.

* In determining the point of extreme humidity, it is supposed, that the air in the jar is not yet saturated, when the vapors begin to be precipitated in an almost imperceptible manner. (Saussure, Essai, § 107 and 123). M. Gay-Lussac has shown, that the hygroscopical property of the glass becomes a source of errors difficult to avoid.

AZURE COLOR OF THE SKY, AND COLOR OF THE SEA AT ITS SURFACE.

The cyanometrical indications contained in this work are, I believe, the first that have been attempted on the sea, and in the equinoctial regions. The instrument I made use of had been compared with that of M. de Saussure. I had the satisfaction, in 1795, to consult this illustrious naturalist on my travelling projects; and he had engaged me to make, at a distance from Europe, a series of observations similar to those he had collected on the chain of the higher Alps *.

I shall not here enter into the theory of the cyanometer, and the necessary precautions to avoid errors. Though this imperfect instrument is yet but little known, naturalists are not less acquainted with the ingenious principle, on which the determination of the extreme points of the scale † are founded. In order to assure myself by direct proof, whether the cyanometrical observations

* Mr. Leslie has expressed the same desire in his work on the propagation of heat, p. 442.

† Mémoires de Turin, t. iv, p. 409. Journal de Physique, t. xxxviii, p. 499. Voyages dans les Alpes, § 2086. Essai sur la Géographie des Plantes, 1807, p. 102. Bouguer appears to have already had the idea of a similar instrument, but of more general use. In speaking of the light reflected by the particles of the air, he says "We should employ, as a term of comparison, painted tablets of different colors." Traité d'Optique, p. 365.

are comparable with each other, I have often placed the instrument in the hands of persons, who had not been accustomed to this kind of measurement, and I have observed, that their judgment on the shades of blue toward the horizon and at the zenith never differed more than two degrees.

The chamois hunters and Swiss herdsmen have at all times been struck with the intense color of the heavenly vault on the summit of the Alps. In the year 1765 Mr. Deluc fixed the attention of naturalists on the phænomenon, the causes of which he developed with equal precision and simplicity. "In the lower part of the atmosphere," says he*, "the color of the air is always paler and weakened by the vapors, which at the same time cause a greater dispersion of the light. The air of the plains becomes deeper, when it is more pure; but it never approaches the vivid and deep tint, which is remarked on the mountains." It seemed to me, that in the chain of the Andes these appearances make less impression on the mind of the natives, because those among them, who scale the summits of the Cordilleras to gather snow, do not come from the region of the low lands, but from elevated plains, which are themselves twelve or fifteen hundred toises above the level of the sea.

* Researches on the Modifications of the Atmosphere, § 931.

I found on examining the cyanometrical observations recorded in my journal, that, from the coasts of Spain and Africa to those of South-America, the azure color of the heavenly vault progres sively augmented from thirteen to twenty-three degrees. From the 8th to the 12th of July, in twelve and a half and fourteen degrees of latitude, the sky was of an extraordinary paleness, without any concrete or vesicular vapor being visible. The cyanometer indicated at the zenith, between noon and two in the afternoon*, only sixteen or seventeen degrees; though the preceding days it had been at twenty-two degrees. I found in general the tint of the sky deeper under the torrid zone, than in the high latitudes; but I have also proved, that, in the same parallel, this tint is paler at sea than on land.

As the color of the firmament depends on the accumulation and on the nature of the opake va-

* The observations were always made at the zenith itself, or near the zenith, but at times when the Sun was distant from that part of the sky, of which the intensity of the blue color was measured. At ten or twelve degrees distance around the Sun, the tint has a local paleness; as on the contrary it has a local intensity, when the blue of the sky is seen, either between two clouds, or above a mountain covered with snow, or between the sails of a ship, or the tops of trees. It is scarcely necessary to remark, that this intensity is only apparent, and that it is the effect of a contrast of two colors of different shades.

pors suspended in the air, we should not be astonished, if during great droughts, in the *steppes* of Venezuela and of Meta, we see the sky of a deeper blue than in the basin of the ocean. A very hot air, almost saturated with humidity, rises perpetually from the seas towards the high regions of the atmosphere, where a colder temperature prevails. This ascending current causes there a precipitation, or rather a condensation of vapor. Part assembles in clouds, under the form of vesicular vapor, at times when we see no clouds appear in the dryer air that reposes on the land; another part remains scattered, and suspended in the atmosphere, the tint of which it renders paler. When, from the summit of the Andes, we turn our eye towards the great South Sea, we often perceive a haziness uniformly spread to fifteen or eighteen hundred toises in height, and covering, as with a thin veil, the surface of the ocean. This appearance takes place in a season, when the atmosphere, beheld from the coast and at sea, appears pure and perfectly transparent; and the existence of the opake vapor is announced to navigators only by the little intensity of the azure color of the sky. We shall hereafter have occasion to return to these phænomena, which modify the extinction of light; and which, like the fogs popularly called dry, remain so confined to the high regions of the atmosphere, that our hygrometers undergo no sensible change.

I have often repeated, in the equinoxial part of the Atlantic Ocean, the experiments of M. de Saussure on the decrement of the intensity of color observed from the zenith to the horizon. On the 14th of July, in latitude 16° 19′, the sky being of the purest blue, the thermometer keeping at twenty-two degrees, and the hygrometer at eighty-eight degrees, I found, toward noon,

at 1° of height,	3° of the cyanometer
10	6
20	10
30	16·5
40	18
60	22
between 70 & 90	23·5

The 30th of June, in latitude 18° 53′, the thermometer being at 21·2°, and the hygrometer at 81·5°, the cyanometric decrement had been somewhat less regular:

at 1° of height,	2·5° of the cyanometer
10	4
20	8·5
30	12
45	15·5
50	18·3
60	21
between 70 & 90	22·4

This decrement has a great analogy with that which was observed at Geneva on the 11th of

April, 1790, and to which Mr. Prevost* endeavoured to apply calculation. We know, that both follow nearly an arithmetical progression, but that at sea there are great irregularities before twenty degrees of height. This zone near the horizon exhibits tints extremely pale, on account of the vapor that lies on the surface of the water, and through which the blue rays are transmitted to us. It is for the same reason, that near the coasts, at an equal distance from the zenith, the vault of the sky appears of a deeper colour on the land side than on that toward the sea.

The quantity of vapor, which modifies the shades of the atmosphere by reflecting white light, is changing from morning to evening; and the cyanometer, observed at the zenith, or near this point, indicates with sufficient precision the variations that correspond to the different hours of the day.

Latitude.	6½ o'clock.	10 o'clock.	Noon.	2 oclock.	5½ o'clock
18° 53′	17°	21°	22·4°	22°	18°
16 19	19	22	23·5	23	20·5
13 51	15	16	17	17	15·8

I was unwilling to omit the last observation, that of the 8th of July, though the sky, by a singular anomaly, appeared that day as pale as we see it

* Journal de Physique, t. lvii, p. 372.

on the continent in the temperate zone. The Sun being at equal distances from the meridian, the tints are deeper in the evening than in the morning, without doubt because the maximum of temperature falls between the hours of one and two. I have not remarked, like M. de Saussure, that the cyanometer was regularly less elevated at noon *, than some time before the passage of the Sun across the meridian; but I have not been able to devote myself with the same assiduity to this kind of investigation.

We must not confound the cyanometrical measures with the experiments, which Bouguer attempted, by means of his *lucimeter*, on the intensity of the light diffused or reflected by the air. This intensity contributes without doubt to modify the more or less azure tint of the heavenly vault; but the two phænomena do not depend directly on the same causes, and there are a great number of circumstances, in which the intensity of the aërial light is very small, while the cyanometer indicates deeper tints. M. Leslie † has observed, for instance, by his photometer, that the light diffused is weaker, when the sky is of a very deep and pure blue, than when it is slightly covered by transparent vapor. So, on the mountains where the

* Cyanometrical observations at Geneva:

6 o'clock.	10 o'clock.	Noon.	2 o'clock.	6 o'clock.
14·7°	22·6°	22·5°	20·6°	17°

† On the Propagation of Heat, p. 441.

intensity of the direct light is the greatest *, the aërial light is very weak, because the rays are reflected by air of less density. A very deep tint corresponds there to the feebleness of the diffused light; and the aspect of the sky on the mountains would resemble that offered by the heavenly vault on the plains, when it is illumined by the feeble light of the Moon, if the state of the aqueous vapor did not produce a sensible difference in the quantity of white rays reflected toward the lower regions of the Earth. In these regions, the vapors are condensed after sunset, and the descending currents disturb that equilibrium of temperature, which has been established during the day. On the ridge of the Cordilleras, the azure of the sky is less mingled with white, because the air there is always extremely dry. The rarer atmosphere of the mountains, illumined by the vivid light of the Sun, reflects almost as few blue rays as the dense atmosphere of the plains enlightened by the feeble light of the Moon. From these considerations it follows, that we ought not to say, with M. de Saussure and other naturalists, who have recently treated on this subject, that the intensity of the blue is greater on the summit of the Alps than in the plains; the color of the sky is only deeper, less mixed with white.

* Laplace, Mécan. Céleste, t. iv, p. 282. Expos. du Syst. du Monde, p. 96.

If we direct the cyanometer toward the parts of the sky very near the Sun, the instrument indicates, near the zenith, as faint tints as those which are observed near the horizon. The causes of this paleness are very different. Near the Sun too intense a light fatigues our organs; and the eye, dazzled by the quantity of white rays it receives at once, becomes almost insensible to the impression of the blue rays. At the horizon, on the contrary, it is not the intensity of the aërial light, that renders the azure tint of the sky pale; before sunset this phænomenon is produced by the white light, reflected by the vapors condensed near the surface of the Earth.

Bouguer has made the curious observation, that, when the Sun is fifteen or sixteen degrees high, there are, on a line parallel to the horizon, two parts of the sky, from 110 to 120 degrees distant from the luminary, where the intensity is at its *minimum*; while we observe the *maximum* in a point diametrically opposite to the sun*. We think, that this circumstance has but little influence on the accuracy of the cyanometrical measures made in the torrid zone; for the greater the elevation the Sun has above the horizon, the more uniformity there is in the distribution of the aërial light†. It even appears, that a part of the sky

* Bouguer, Traité d'Optique, p. 71 and 367.

† Ibid, p. 74.

may reflect a greater or less quantity of light, without any indication of a deeper or fainter tint by the cyanometer.

I shall not enlarge any farther on the analogy, that exists between the results obtained by the cyanometer of Saussure and the lucimeter of Bouguer. This subject is one of the most delicate investigations in optics; and the tint of the sky deserves so much more the attention of naturalists, as the ingenious experiments of Mr. Arago have recently proved, that the aërial light is composed of rays not all of the same nature, since it contains some that are insusceptible of polarization.

If the cyanometer indicate, I will not say the quantity, but the accumulation and the nature of the opake vapors contained in the air, the navigator is in possession of a more simple manner of judging of the state of the low regions of the atmosphere. He attentively observes the colour and figure of the solar disk at its rising and setting. This disk, beheld across the strata of air that lie immediately upon the ocean, announces the duration of fine weather, and the slackness or strength of the wind. It is a kind of diaphanometer*, the indications of which have been interpreted with greater or less certainty for ages.

* See the description of the apparatus, to which Saussure has given this name in the Mémoires de Turin, vol. iv, p. 425.

Under the torrid zone, where the meteorological phænomena follow each other with great regularity, and where the horizontal refractions are more uniform, the prognostics are surer than in the northern regions. A great paleness of the setting Sun, a wan color, an extraordinary disfiguration of its disk, are almost unequivocal signs of a tempest; and we can scarcely conceive, how the state of the low strata of the atmosphere, which this natural diaphanometer shows us, can be so intimately connected with meteorological changes, that take place eight or ten hours after the setting of the Sun.

Mariners have carried the physiognomical knowledge of the sky to a much higher state of perfection, than the inhabitants of the fields. Viewing only the ocean, and the sky which seems to repose upon its surface, their attention is continually fixed on the slightest modifications of the atmosphere. Among the great number of meteorological rules, which pilots transmit to each other as a kind of inheritance, there are several that evince great sagacity; and, in general, prognostics are less uncertain in the basin of the seas, especially in the equinoctial parts of the ocean, than on the continent, where the configuration of the ground, mountains, and plains, interrupt the regularity of the meteorological phænomena. The influence of the lunations on the duration of

tempests; the action exercised by the Moon at its rising, during several successive days, on the dissolution of the clouds; the intimate connection that exists between the descent of marine barometers and the changes of weather; and other similar facts; are scarcely observed in inland countries comprised in the variable zone, while their reality cannot be denied by those, who have long been in the habit of sailing between the tropics.

I attempted to apply the cyanometer to measure the color of the sea. Though this color is commonly green, we have no need of a *chlorometer* to estimate the intensity of its tint. In this experiment there is no question but of the strength of the color, of the lighter or deeper shade, and not of the individual nature or quality of the tint. In fine calm weather the colour of the ocean has been equal to the thirty-third, the thirty-eighth, sometimes even the forty-fourth degree of the cyanometer; though the vault of the sky was very pale, and scarcely reached the fourteenth or fifteenth degree. It would be useless to repeat these experiments when the atmosphere is loaded with clouds, or in the shadow of a vessel. When, instead of directing the cyanometer toward a great extent of open sea, we fix our eyes on a small part of its surface through a narrow aperture, the water appears of a beautiful ultramarine colour. Toward evening, on the contrary, when the edges of

the waves, illumined by the Sun, are of an emerald green their surface, on the shady side, has a purple reflection.

Nothing is more striking than the rapid changes, which the ocean undergoes beneath a serene sky, where no variations whatever are to be perceived in the atmosphere. I do not here speak of the whitish and milky tint, that marks the waters of shoals, and in soundings, which is owing only to the sand suspended in the liquid, since it is perceived in places, where the bottom, in twenty or thirty fathoms water, is no way visible; I speak of those extraordinary changes, by which, in the midst of the vast basin of the equinoctial ocean, the water passes from an indigo blue to the deepest green, and from this to a slate gray, without any apparent influence from the azure of the sky, or the colour of the clouds.

The blue tint of the ocean is almost independant of the reflection of the sky. In general the sea between the tropics is of a more intense and purer azure than in high latitudes; and this difference is remarked even in the Gulf-stream. The ocean often remains blue, when, in fine weather, more than four fifths of the sky are covered with light and floating clouds. They who do not admit Newton's theory of colours consider the blue of the sky as the black of space seen through a medium, the transparency of which is disturbed by

vapors *, this explanation they might extend to the blue tint of the Ocean.

Whatever relates to the color of the water is extremely problematic. The green tint of the snow waters, that flow from the glaciers of the Alps, and which contain very little air in solution, might induce us to believe, that this color is appropriate to water in its greatest purity. We address ourselves in vain to chemistry to explain this phænomenon, or that of the blue color of the Rhone near Geneva: there is hitherto no proof, that waters exist which contain a greater or less degree of hydrogen; and the refrigeration of the seas in tempests is much too weak, to permit us to attribute the reflection of different colored rays to the mere change of density. It is no way probable, that the green color of the water is owing to the mixture of yellow rays from the bottom, and blue rays reflected by the water †; for the open sea is often green, where it is more than eight hundred fathoms deep. Perhaps, at certain hours of the day, the red or yellow light of the Sun contributes to the colouring it green ‡.

* Antonio de Dominis, la Hire, and Mr. von Goethe. (*Mém. de l'Acad.*, t. ix, p. 615. *Farbenlehre*, t. i, p. 59.)

† Décade Egyptienne, vol. i, p. 101.

‡ The beautiful greenish blue color of ice, when we see it in a great mass, is a phænomenon well worthy of investigation, and known by every naturalist, who has visited the glaciers of the Alps.

The waves, like movable and inclined mirrors, progressively reflect the shades and tints of the atmosphere from the zenith to the horizon. The motion of the surface of the water modifies the quantity of light, that penetrates toward the inferior strata; and it may be conceived, that those rapid changes of transmission, which act as it were like changes of opakeness, may, when they are united to other causes unknown to us, change the tint of the ocean.

DIP OF THE MAGNETIC NEEDLE. INTENSITY OF THE MAGNETIC FORCES.

The variations of terrestrial magnetism belong to a kind of phænomena, on which I have employed myself with singular predilection, during the course of my travels, and in the subsequent years. The objects to which I directed my researches were, first, the dip of the magnetic needle; secondly, the variation, or angle which the magnetic meridian makes with the meridian of the place; thirdly, the horary variations of the variation; fourthly, the intensity of the magnetic forces, measured by the duration of the oscillation of a horizontal or vertical needle*. The extent

* When we measure the intensity by the oscillations of a needle in a horizontal plane, we must correct the results by the dip observed in the same place. This correction is unneces-

of the surface of the Globe, in which I have been enabled to determine the magnetic phænomena with the same instruments, and employing similar methods, was one hundred and fifteen degrees in longitude, and is comprised between fifty two degrees north and twelve degrees south latitude. This vast region is so much the more interesting, as it is traversed by the magnetic equator; so that the point where the dip is nought, having been determined by land, and by astronomical means, we may, with respect to the two Americas, convert, with precision, the terrestrial latitudes into magnetic latitudes. This conversion, indispensable for the study of the complicated laws of magnetism, is, on the contrary, very problematic, when we compare observations of the magnetic dip made in meridians very remote from each other; and when we consider the magnetic equator as a great circle, without inflexion, and without irregularity of curve.

sary, when we employ a dipping needle, which oscillates in the plane of the magnetic meridian. The number also of these oscillations, compared with the number of those which the same needle makes in a plane perpendicular to the magnetic meridian, determines the dip of the place. This method of finding the dip by an instrument without a divided limb affords more precision near the magnetic equator, than in the northern regions: it served to verify the exactness of a part of my observations, published before my return to Europe by M. de La Lande. (*Journal de Phys.*, vol. xlix, p 429.)

Notwithstanding the considerable degree of perfection, which Mitchell and Nairne had attained in the construction of dipping needles, these instruments, before the year 1791, had not reached that degree of exactness, which they have now attained. If La Caille, Dalrymple, Cook, Bayly, and Lord Mulgrave have succeeded in obtaining excellent results, it is because these able observers made numerous comparative experiments, and took the average of a great number. The compasses employed in La Pérouse's expedition were those made use of by Captain Cook in his last voyage round the world. We must suppose, that these instruments were out of order, or of difficult use; for the dips observed on board the *Astrolabe* often differ five, six, or eight degrees from those obtained the same day on board the *Boussole*. This uncertainty had induced the celebrated Borda to apply himself, conjointly with M. Le Noir, to the improvement of the dipping needle. This navigator, to whom astronomy is indebted for the use of repeating circles, has also furnished travellers with the means of making accurate observations on the magnetic dip. Borda's compass was successfully employed in the voyage of Vicead-miral d'Entrecasteaux, in that of Captain Baudin, and in the excursions of M. Nouet in Egypt. If we add the results obtained in these different voyages to those I have collected during seven years in the two divisions of America, in Spain,

France, Italy, Switzerland, and Germany, we shall have a great mass of observations, comparable*

* The observations of the dipping needle made by de Rossel, Freycinet, Nouet, Gay Lussac, and myself, are so much the more adapted to be compared with each other, as they embrace but a very short portion of time. Le Monnier *(Lois du Magnétisme*, p. 57*)* and Lord Mulgrave *(Voyage to the North Pole*, p. 68) still admitted the invariability of the magnetic dip: but Messrs. Gilpin and Cavendish proved, in 1806, by direct experiments, that the dip of the needle is subject, like the variation, to annual oscillations, though extremely slow. The cities of London and Paris are hitherto the only places, where the extent of these oscillations is known. The dip at London, in 1775, was 72° 30′, and in 1805, 70° 21′ (Phil. Trans., vol. lxvi, pl. 1, p. 401). We cannot admit, with P. Cotte (Journ. de Physique, t. lxvi, p. 277), that, before the year 1808, the dip of the magnetic needle was not known with precision at Paris. I had determined it with a great deal of care, conjointly with M. de Borda, in 1798, before my departure for Spain. It was then 69° 51′. M. Gay-Lussac found it in 1806, 69° 12′. On the 7th of October, 1810, the dip at Paris was 68° 50′; and on the 10th of November, 1812, 68° 42′. The first of these two experiments was made by Mr. Arago and myself; the second by Mr. Arago alone. The particular observations did not differ three or four minutes. The poles of the needle were changed several times; and all imaginable precautions were employed, in the use of Borda's compass, to avoid errors. From these observations it results, that from 1775 to 1805 the dip diminished at London 4′ 18″ yearly: at Paris the annual diminution, from 1798 to 1812, was 4′ 54″. I should think it hazardous to go back to anterior times, when the instruments were too imperfect, and when observers employed too little nicety in their magnetic experiments.

with each other, and worthy of exercising the sagacity of geometricians.

Though our passage from Corunna to Cumana lasted thirty seven days, I could collect, during this space of time, only twelve good observations of the magnetic dip. I had caused an addition to be made to Borda's compass, by an able artist of Madrid, Mr. Megnié, of a suspension with a double movable ring, like that known under the name of Cardan's suspension. By these means the instrument might be tied by a very long cord to a part of the poop, which appeared nearly free from iron, and where small portions of this metal were very equally distributed. I ascertained the advantages of this position by determining the dip during a dead calm, on the deck, and in several parts of the vessel below. During the course of those observations, I found the direction of the magnetic meridian in seeking the minimum of the the dips. Most commonly I had to judge of the magnitude of the angle by taking, among a great number of very small oscillations, the mean of the elongations toward the north and the south. I constantly employed two different needles; their centring was verified by comparing the indications of the two extremities of the same needle, and inverting it, or successively directing the divided face of the limb east and west. I think I may be certain, that observations made when under sail

may attain an average exactness of twelve minutes of the centesimal division*.

* The angles given by Borda's dipping compass are expressed in centesimal degrees and decimal parts. The verifications of the instrument, which can be made on land, and which I have constantly employed with Mr. Gay-Lussac, during the course of the observations published in the Memoirs of the Society of Arcueil, are reducible to the following: 1st, giving a horizontal position to the azimuth circle, by means of a bubble level and a thread level; 2ndly, finding the direction of the magnetic meridian, either *a)* by correspondent dips, or *b)* by adding, on the azimuth circle, one hundred degrees to the point which corresponds to the perpendicular position of the needle; or finally *c)* by the *minimum* of the dips; 3dly, correcting the eccentricity of the needle, by observing the superior and inferior points; 4thly, examining whether the magnetic axis of the needle coincides with its physical axis, by observations to the east and the west; 5thly, correcting the want of equilibrium in the needle by changing the poles. The slight differences, which will be noticed between the results published in this narrative, and those that were inserted, during my journey, in several public papers (Journ. de Phys. t. iv, p. 433; Mag. Encyclop. an 8, p. 376; Zach, Monatl. Corresp. t. i, p. 402), arise from my having sometimes neglected taking the average between the observations made to the east and the west, and because the latitudes and longitudes observed had not always been reduced by estimation to the same time, when the magnetic dip had been determined.

Dip of the Magnetic Needle, and Intensity of the Magnetic Forces in the North Atlantic Ocean, in 1799.

North Latitude.	West Longitude.	Magnetic Dip. Centesimal Divisions.	Numb. of Oscillations in 10 minutes.	Remarks.
38° 52′	16° 22′	75·76°	242	Good observation.
37 26	16 32	75·35	242	Almost perfect calm.
34 30	16 55	73·00	234	Perfect calm.
31 46	17 4	71·90	237	Doubtful, especially the intensity.
28 28	18 33	69·35	238	Good.
24 53	20 58	67·60	239	Very good.
21 29	25 42	64·65	237	Good.
19 54	28 45	63·52	236	Good.
14 15	48 3	56·30	239	Good.
13 2	53 15	50·67	234	Dip good. Intensity doubtful.
11 1	54 51	47·05	237	Good.
10 46	60 54	46·95	229	Good.

Part of these observations served as a basis to the theories and calculations of Messrs. Loewenoern, Biot, and Kraft* ; they give the direction of the equator, or of the magnetic parallels, with so much the more precision, as I took the same pains in examining the dip, as in ascertaining the geographical position of the vessel. The most accurate observations on the variation of the needle, on its dip, and on the intensity of the magnetic forces, would be of little value, if the traveller were not provided with the instruments necessary to ascertain astronomically the latitude and longitude of the place where the different phænomena of terrestrial magnetism were observed.

I shall not speak of the attempt I made during the passage, to determine the curves of the magnetic variation. The results obtained at sea by the best azimuth compasses are so uncertain, that, according to the testimony of the most experienced navigators†, errors of two or three degrees often occur. Even supposing them only one degree, this uncertainty, augmented by the slow

* Danske Vid. Selskabs Scrivter, 1802, p. 295. Journ. de Phys., t. lix, p. 287. Mém. de Pétersbourg, 1809, t. i, p. 248. See also Mollweide's Attempt to generalize the Theories of Euler and Mayer, in Gilbert's Annalen, t. xxix, p. 1 and 251.

† Voy. de Vancouver, t. i, p. 40 and 99. De Rossel, in the Voy. de d'Entrecasteaux, t. ii, p. 172. Cook's second Voyage, vol. i, p. 24.

changes of the variation in different meridians, would still throw much doubt over the real position of the curves, which are attempted to be traced on variation charts*.

On comparing the observations made during several voyages, it appears, that we had cut the curve of no variation in latitude 13° north, and longitude 53° and 65° west: this curve is now prolonged toward Cape Hatteras, and toward a point in Canada, in 33° 27′ north latitude, and 70° 44′ west longitude. Before the first voyage of Christopher Columbus, in 1460, the variation was nought near the island of Corvo; but the progress of the curve of no variation toward the west is not the same in all its parts, and it is sometimes retarded by the local influence of the continents and islands, which form so many particular systems of magnetic forces. Thus it seemed stopped for some time by the southern extremity of New Holland; and at Jamaica and Barbadoes the variation has not undergone any per-

* The uncertainty of the observations of the magnetic needle made at sea does not arise solely from the rolling and pitching of the vessel, or the imperfection of the azimuth compasses; it is in a great measure caused by the masses of iron spread through the vessel, and acting unequally, according to the direction in which it is steered. Loewenoern, in the *Nye Samling* of *Danske Vid. Selsk. Skr.*, t. iii, p. 117, and t. v, p. 299. *Zach, Mon. Cor.* 1800, p. 529. *Flinders*, in the Phil. Trans. 1805, p. 187.

ceptible changes for one hundred and forty years past*.

The intensity of the magnetic forces is another very important phænomenon, to which naturalists have hitherto very little attended. Graham and Musschenbroeck had attempted to measure the diurnal variations of this force by the velocity of the horizontal oscillations of a magnetic bar†; but it appears, that Borda was the first, who had the idea of making the same dipping needle oscillate in different places of the Globe. The attempts of this learned navigator did not afford, as he has often assured me, any precise result, on account of the friction, which the ancient needles underwent on their axis. At this period men were often satisfied with making the needle of the variation compass oscillate: and in the manuscript account of Borda's Voyage to the Canaries it is expressly stated, in speaking of the modifications of the intensity of the magnetic forces measured by the velocity of the oscillations, that, at the summit of the Peak, he had counted ten oscillations of the card in 97″ of time; while at Santa Cruz their duration had been 94″, at Cadiz 103″, and at Brest

* Thomson's Hist. of the Royal Soc., p. 461. Phil. Trans. vol. 50, p. 330 and 349. (The Oriental Navigator, 1801, p. 650.)

† Phil. Trans. vol. 33, p. 332. Thomson's Hist. of the Royal Soc., p. 461. Diss. de Magnete, Exp. 102 and 107.

113″. M. Le Monnier, in his work on the *Laws of Magnetism* *, observes how desirable it would be, to know the relation between the oscillations of the same needle at Peru, and in the north of Europe; but a note added to his magnetic planisphere † shows, that he had not a very accurate idea of the causes, which modify the intensity of the total force. According to Cavendish ‡, this intensity must be the same over the whole surface of the Globe; and the opinion of this great natural philosopher must have had a very considerable influence on those, who had not had an opportunity of interrogating nature by direct experiments.

In this state of uncertainty, the Academy of Sciences at Paris very earnestly exhorted M. La Pérouse to make, during the course of his voyage round the world, experiments on the intensity of the magnetic forces. "It is known", say the commissioners §, in the instructions communicated to the naturalists engaged in the expedition, "that at Brest, Cadiz, Teneriffe, Goree on the coast of Africa, and Guadaloupe, the intensity is sensibly the same. It would be interesting to repeat these experiments, reckoning the magnetic force by the duration of the oscillations of a good dipping

* Introduction, p. 25.
† Mém. de Paris, 1786, p. 43.
‡ Phil. Trans., 1778, p. 390.
§ Voyage de La Pérouse, t. i, p. 160.

needle, at sea, in very calm weather. It would be above all important to know the magnetic force, where the dip is the smallest." The imperfection of the compasses put on board M. La Pérouse's vessels no doubt prevented the astronomers in this expedition from paying attention to investigations of this kind, and the wishes of the academy of sciences were fulfilled only in the voyage of d'Entrecasteaux, and in that of which this work gives the narrative. Among the great number of valuable observations for which we are indebted to M. Rossel, there are five on the oscillations of the magnetic needle * made at Brest, at Teneriffe, at Van Diemen's Land, at Amboyna, and at Java. For my part, I have determined, jointly with Messrs. Gay-Lussac and Bonpland, from 5° of magnetic latitude south, to 60 magnetic latitude north, the intensity of the forces in a hundred and eighty places belonging to two systems of particular attractions †. In the space

* These observations were published only in 1808 (Voy. de d'Entrecasteaux, t. 2, p. 287, 291, 321, 480, and 644); but they were made eight years before my journey to the Orinoco. I was acquainted with them as early as the year 1805, immediately after having communicated to the first class of the Institute the general results of the progressive decrement of the magnetic forces from Paris to the magnetic equator. *See* the memoir, which I published at that time, conjointly with Mr. Biot, in the sixtieth vol. of the Journ. de Physique.

† On account of the inflexions of the magnetic equator, we

of three years, I have been enabled to procure the oscillation of the same needles, or needles compared with each other, at Lima, under the magnetic equator, at Mexico, at Naples, and at Berlin, which afforded me the means of determining the relation that exists between the magnetic *charges* of the Globe in different climates. From these extensive operations, an account of which will be separately published, it follows, that, supposing the intensity of the forces under the equator = 1, this intensity is, at Naples, 1·2745; at Paris, 1·3482; and at Berlin, 1·3703.

We see already, that from the thirty-eighth to the thirteenth degree of terrestrial latitude, in the part of the northern Atlantic Ocean to which the preceding table refers, the number of the oscillations diminishes from 242 to 234, while the dip varies from 75·76° to 50·67° of the centesimal division. I endeavored to make these observations in calm weather, and when the vessel oscillated in a plane perpendicular to the plane of the limb of the compass. The oscillations of the needle are scarcely disturbed by those of the vessel, the latter having, in a uniform wind, all the regularity of an isochronous pendulum. In general the rate, which the magnetic variations and the

may consider the points of the Globe that differ little in magnetic longitude as belonging to one system of forces. The longitudes are computed from the point of intersection between the terrestrial and magnetic equators.

dip follow in different longitudes, appears more regular in the basin of the sea, than on continents where the inequalities of the surface, and the nature of the rocks of which the surrounding mountains are composed, cause frequent anomalies. As to the duration of the oscillations, it sometimes undergoes irregularities, even in the middle of the seas *; no doubt because the stratum of water is too thin, to prevent the needle from being affected by the unequal distribution of the magnetic forces in the interior of the Globe. The mathematical theory of the tides, it is true, makes it probable, that the mean depth of the ocean is at least four leagues †; but we know, from the aerostatic voyage of M. Gay-Lussac, that in rising perpendicularly from the surface of the Earth 3600 toises, no sensible change is perceived in the intensity of the magnetism. We cannot therefore admit, that the sea is much deeper in those latitudes, where, under the same magnetic parallel, we see the number of oscillations diminish.

I did not regret my not having embarked the apparatus, which Saussure calls a *magnetometer* ‡,

* *See*, in the Journal, my observations made in 34° 30′, and 14° 15′ of north latitude.

† From the small height of the tides, in open seas, and the ratio of the density of the sea to that of the land. (La Place, in the Mém. de Paris. 1776, p. 218.

‡ Voyage dans les Alpes, §. 458 and 2103. I find the first notion of a magnetometrical apparatus in Hooke's posthumous

and which Mr. Paul constructed for me at Geneva. I am inclined to think, that the variations of intensity, believed to have been seen in the same place, by means of this complicated instrument, were the effect of involuntary illusion. M. de Saussure thought, that the magnetic force diminished both on the mountains and during the great heats of summer, while Mr. Blondeau * believed, that he had found by an instrument of his own invention, that a high temperature of the atmosphere increased the intensity of the magnetism. Neither of these assertions has been confirmed by accurate experiments. There is no doubt, that periodical variations in the intensity of the magnetic forces exist in the same place; as have already been discovered in the variation, and even to a certain point in the dip† of the magnetic needle: but these variations of intensity appear to be infinitely feeble, since they cannot be perceived, if we employ, in-

works. This natural philosopher, a man of extraordinary sagacity, thought, in 1680, of measuring, by means of a steelyard *(statera)*, the force with which a magnet attracts iron at different distances. *Posth. Works*, p. 23. See also Brook Taylor's experiments, made in 1715, *Phil. Trans.* vol. xxxi, p. 204.

* On the apparatus, which Mr. Blondeau called magnetometer, before Saussure, See Mém. de l'Académie de la Marine de Brest, t. i, p. 421.

† Horary and diurnal variations of the dip have not yet been observed; but a slow change takes place in the space of several years.

stead of the magnetometer with a perpendicular rod terminated by a ball of iron, the delicate apparatus of Coulumb, that is, the oscillations of a small needle contained in a glass case, and suspended by an untwisted silk thread *. Besides, the two instruments are not founded precisely on the same principle; for the artificial magnet having a quantity of fluid, which is as it were independant of that of the Earth, it may be conceived, that

* At the hospice of Mount-Cenis, and at Rome, Mr. Gay-Lussac and myself have observed the oscillations of the same needle by day and by night, in very different atmospherical temperatures. The result of these experiments was, that, if there exists a horary variation in the intensity of the magnetic forces, it does not alter the duration of the oscillations a twelve hundredth. At Milan, the same needle made, on the the 15th of April, 1805, in the interior of the city, near the cathedral, sixty oscillations in 4′ 56·8″; and on the 7th of October, in a meadow without the walls, in 4′ 56·4″. At Rome the duration of the oscillations was the same to a few tenths of a second, at the Villa Borghese, at Monte-Pincio, and on the road to Tivoli. Experiments of this sort are susceptible of so great an exactness, that in different experiments made on the top of Mount Cenis, two hundred and fifty oscillations lasted 1229·3″, 1229·2″, 1229″, and 1229·5″. At Rome we successively found, with a chronometer of Breguet, 1169·2″, 1169·2″, 1169″, and 1169·5″. I have thought it right to note in this place these results, in order to prove, that the experiments made on the intensity of the magnetic forces, and recorded in this work, are not subject, in a small extent of ground, to that great number of local and horary influences, which affect the observations on the variation of the magnetic needle.

the magnetometer, conveyed to different climates, cannot give the same results as the oscillatory apparatus.

In speaking of the physical observations made during the passage from Ferrol to Cumana, I have not mentioned my experiments on the purity of the air, and its electric charge*. The former were made by means of the nitrous gas in the narrow tubes of Fontana's eudiometer, and seemed to indicate a greater portion of oxygen in the strata of the atmosphere lying on the sea, than in those which surround continents. We know at present, that, if eudiometrical variations exist, they must be less than two thousandths; and that the results I obtained in 1799 do not merit confidence, on account of the too imperfect means then employed in the analysis of the atmosphere.

With respect to electrometrical experiments, it was impossible for us, either on board the Pizarro, or any other vessel in which we afterward sailed, to perceive at sea the least sign of tension, on making use of Bennet's and Saussure's excellent electrometers. M. Bonpland has often taken the pains to carry these instruments, furnished

* I took the greater interest in this kind of experiments, because, a short time before my departure from Germany, I had devoted myself to a very extensive inquiry into atmospherical electricity at the foot of the high mountains of Salzburgh. The results of my labours are related in the Journal de Physique, an 7.

with long metallic stems and a lighted match, on the masts and yards farthest from the hull of the vessel. These trials were repeated in the South Sea, on board a Spanish frigate with very high masts; but the gold leaf, the dryest straws, or little balls of elder pith, which are electroscopical substances, never indicated the slightest divergence. Is it the surface of the ocean, that deprives the lower strata of the atmosphere of its electricity? or do the hull of the vessel, the sails, and masts, act as powerful conductors? If this action take place, why did not our electrometers indicate electricy in open boats, while, on the coasts of Peru, we have seen signs of a strong tension, when a damp wind blew from the sea?

It is the duty of a natural philosopher candidly to relate the circumstances in which certain experiments did not succeed. As two thirds of our atmosphere lie on the basin of the seas, meteorology would gain considerably, if we knew the electric state of this part of the aerial ocean. We may be tempted to repeat the experiments I have just described with the microelectrometers of Weiss, Gersdorf, and Maréchaux*. These instruments discover electricity near a wall, in the shade of a tree, every where almost, when Bennet's and Saussure's electrometers indicate none. They are preferable to electric points fastened to

* *Gilbert, Annalen*, B. xv, p. 98.

flying kites, or small balloons, because the electricity marked by these last is most frequently the mere result of the ascending motion, as has been proved by the fine experiments of Mr. Erman *.

I have had no better success than the majority of travellers in ascertaining the degree of saltness of the sea †, which varies with the latitude. From the small number of accurate observations I obtained by means of an areometer by Dollond, differing little from that of Nicholson, it follows, that the specific gravity of the sea-water augments pretty regularly from the coasts of Gallicia to Teneriffe, while it diminishes anew from latitude 22° 52′ to 18° 45′. In these regions, in the twenty-fourth and thirtieth degrees of longitude, a large stripe of the ocean is less salt than the rest.

The muriat of soda amounts to 0·028 from the parallel of 18° 8′ to that of 12° 34′, between the

* *Ibid.* p. 389 and 503.

† Mr. Proust, struck with the traces of mercury which he he had met with in all the muriats of soda of Spain (*Nicholson's Journ. of Nat. Phil.*, 4to ed., vol. iii, p. 376), requested me, at my departure from Madrid, to suspend, during the passage, a thin plate of gold or silver, to the poop of the vessel, to see if it would offer any traces of amalgama. I followed the advice of this celebrated chemist, though I had little confidence in the success of this experiment; but the thread, to which the plate was tied, broke a few days after I had put my apparatus into the water.

thirtieth and fifty fourth degrees of longitude. It seemed to me, that, in the part of the Atlantic comprised between the coasts of Portugal and Cumana, the water is a little salter to the south of the tropic of Cancer, than under the temperate zone; and I should be induced to generalize this fact, if the experiments made during Cook's last voyage did not peremptorily prove, that this difference does not exist in every meridian. Horizontal currents, which cross the ocean at its surface; and oblique currents which mingle the strata of water, placed at different depths; modify the saltness of the seas; and supposing even, that the absolute quantity of the muriats dissolved in the ocean has not been augmented by the action of submarine volcanoes, but has remained the same for thousands of years, it is not the less probable, that the distribution of this salt in different parts of the Globe, undergoes, from time to time, considerable changes.

JOURNAL

OF A

VOYAGE FROM THE COASTS OF SPAIN

TO THOSE OF

SOUTH AMERICA,

OR FROM

CORUNNA TO CUMANA.

[The longitude was found by a time-keeper of Lewis Berthoud, No. 27. The temperature of the ocean indicated is that of the surface of the water. The cyanometrical observations were made at the zenith. The thermometer exposed to the air was placed to the windward, and in the shade. When an observation of the Sun at the meridian could not be obtained, Douwe's method of double altitudes was employed. The latitudes and longitudes are given for noon.]

Days of the month.	North latitude.	West long.	PHYSICAL OBSERVATIONS.
1799			
June 5	43° 28′	10° 45′	Departure from the port of Corunna.
			Temperature of the ocean, 15·4° centesimal: air 10·2°.
			Hygrometer, whalebone, 44°, or 80·4° of Saussure's hair hygrometer.

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
June 5	43° 28′	10° 45′	*Cyanometer*, 13°. Floating clouds; wind N.E. fresh; rough sea. *Dip* of the magnetic needle observed at the port of Ferrol, 76·6°, centigrade division. *Intensity* of the magnetic forces, in Gallicia, expressed by 243 oscillations in ten minutes of time.
6	44 0	13 7	*Temperature* of the sea, 16°. Temperature of the air, 9°; brisk gale; the sea rough and very stormy.
7	42 7	15 24	Beyond the parallel of Cape Finisterre, at forty-two leagues distance from this cape. Gentle gale, N.N.E; air, 18·7°. *Cyanometer*, 14°.
8	41 0	16 9	Wind north east, very weak. Temp. of the air, 12·5°. *Hygrometer*, 45·6° Deluc (82° Saussure).
9	39 10	16 18	*Temperature* of the sea, 15°; temp. of the air, 14° 5′; northerly wind, feeble; serene sky. *Thermometer* exposed to the sun, 16° 9′; Sun's force, 2° 4′; in the parallel of Peniche. *Cyanometer*, 15° (the blue of the ocean measured with the same instrument 35°). Hygrometer the whole day, 81°—83° Saussure.

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
June 9	39° 10′	16° 18′	*Dip* of the magnetic needle (latitude 38° 52′ and longitude 16° 22′) 75·76°. *Magnetic intensity*, 242 oscillations; good observation. The current, which sets E. by S. and S. E., begins to be felt.
10	37 26	16 32	Light north-west wind, fine weather, almost in the parallel of Cape St. Vincent, and between this cape and the Azores at eighty leagues to the west of the cape. *Temperature* of the ocean, 15·2°; temp. of the air, 15°; thermometer exposed to the Sun, 18·7°; Sun's force, 3·7°. *Hygrometer* at noon, 47° Deluc (83·5° Saussure). At three in the afternoon, 50° Deluc. (85·2° Sauss.) *Dip* of the magnetic needle, 75·35°; oscillations 242. *Cyanometer*, 14°; blue color of the sea, nearly calm, 44°
11	36 4	17 5	*Temperature* of the sea, 15·2°; temp. of the air, 18·6; weather a little cloudy. At seven in the evening, temp. of the sea, still 15·2°; temp. of the air, 17·4°; sea somewhat ruffled. *Hygrometer*, at seven in the evening, 51° Deluc (86·4° Saussure).

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
June 12	35° 8′	17° 15′	Calm, hazy weather; a little rain at nine in the morning; at fifty leagues distance from the coasts of Africa, to the west of Cape Blanco. *Temperature* of the sea, 16·2°; temp of the air, 20·6°. At eight in the evening, the sea 16·2°; the air 15·7°. *Hygrometer*, 47·8° Deluc (84° Saussure).
13	34 30	16 55	Variable weather, calm, rainy. From eleven in the morning clear sky, without clouds; in the night, breeze from the west. *Temperature* of the sea, 16·3° (at a depth of fifteen metres, 15·7°); temperature of the air, 19·7; thermometer exposed to the Sun 20·3°; Sun's force 0·5°; temperature of the air at eleven at night, 13·7°. *Hygrometer*, 54·5° Deluc (87·5 Saussure). *Cyanometer*, 16°; blue colour of the sea 34°. The sky has a reddish blue tint, almost violet, a singular phænomenon, which I have also sometimes observed in the Pacific Ocean, especially in the southern hemisphere, and without the sea being green.

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
June 13	34° 30′	16° 55′	*Dip* of the magnetic needle, 73·0°, found in a dead calm. *Magnetic intensity*, 234 oscillations.
14	32 16	17 4	To the east of the isle of Madeira, at forty-five leagues distance; strong breeze from the west; sea very rough. *Temperature* of the sea, notwithstanding the height of the waves, 17·7°; temperature of the air, 16·8°. *Dip* of the magnetic needle, 71·90, somewhat doubtful (latitude 31° 46′ longitude 17° 4′). *Magnetic intensity*, 237, very doubtful.
15	30 36	16 54	Fine weather, sea almost entirely calm. *Temperature* of the water, 18·7°: temperature of the air 20·6°. *Progressive variations* of the hygrometer and thermometer observed carefully in the shade, and four metres above the surface of the ocean:

Hours.	Saussure's hygrom.	Centigrade therm.	
At 21½	85·3°	21·2°	calm.
22½	85·7	20·0	little wind.
23½	85·8	20·0	idem.
0½	85·3	21·4	calm.
2½	84·2	23·7	idem.
3½	84·3	22·5	idem.
6½	85·2	20·0	idem.
7½	86·2	19·8	idem.

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
June 15	30° 36′	16° 54′	*Sun's force*, 3·1°; thermometer in the shade, 20·6°; thermometer exposed to the Sun, 23 7°. Between Cape Aguer and the Salvage islands, twenty-three leagues east of the latter. Pilot's reckoning, compared with the longitudes given by the marine time-keeper, indicates a current setting toward the south-east.
16	29 18	16 40	Fine weather; westerly wind, very feeble; near the western coasts of the island of Lanzerota. *Temperature* of the ocean, 19·3°; air, 18·9°. *Cyanometer*, 22° (colour of the sea ·40°). *Sun's force*, 3·6°; thermometer exposed to the Sun, 22·5°. Variations of the hygrometer and thermometer, the air being very little agitated.

Hours.	Saussure's Hygrometer.	Centigrade Thermometer.
21½	85·8°	19.5°
22½	85·0	18·7
23½	84·8	18·7
0½	83·8	20·0
1½	83·4	21·2
2½	83·3	21·8
3½	83·5	22·5
4½	83·5	21·2
5½	83·8	21·2
6½	85·0	19·3

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
June 17	29° 21′	16° 6′	Clear weather, calm at intervals: on the coasts of the small island of Graciosa, and in the archipelago of islets that lie to the north of it. *Temperature* of the Ocean, in the channel, between the islands of Alegranza and Santa Clara, where the sea is only sixty-two metres deep, 17·8°, consequently 1·5° colder than in the open sea, in the same parallel. Temperature of the air, 20°.
18	29 5	17 10	*Temperature* of the sea, far beyond soundings, 18·7; temperature of the air, 18·3: gentle breeze; clear weather. Sun's force, 1·6°; thermometer exposed to the Sun, 19·9°.
19	28 28	18 33	Arrival in the road of Santa Cruz in the island of Teneriffe. *Dip* of the magnetic needle, 69·35°. Magnetic *Intensity*, 238 oscillations. Abode at the island of Teneriffe, from the 19th to the 25th of June.
25	26 51	19 13	*Temperature* of the sea, 20°; air, 18·8°; strong breeze at N. E.
26	25 15	20 17	*Temperature* of the ocean, 20°; temperature of the air, 21·2°. *Dip* of the magnetic needle, 67·60°: very good observation (lat. 24° 53′, and long. 20° 58′).

Days of the month	North lat.	West long.	PHYSICAL OBSERVATIONS.
June 26	25° 15′	20° 17′	*Intensity*, 239 oscillations, computed in calm weather, to the south-west of Cape Bojador, at 62 leagues distance.
27	22 52	22 13	Sea, 20°; air, 20·1°: fresh breeze from the N. E., the Sun's force appearing only 2°. In the night, temperature of the air 19·3°.
28	21 30	25 23	Air, 22°; brisk wind from the N. E.: 90 leagues north of Cape Verd. *Dip* of the magnetic needle, 64·65°: very good observation (lat. 21° 29′, and long. 25° 42′). *Oscillations* 237.
29	20 8	28 51	*Temperature* of the sea, 21·2°; air, 20°. From ten in the morning to five in the evening, the thermometer did not vary 0·8°, while the breeze blew very strong. *Dip* of the magnetic needle, 63·52°. Oscillations 236 (at 60 leagues N. N. W. of the island of Santa Antonio): latitude 19° 54′, longitude 28° 45′.
30	18 53	30 41	*Temperature* of the sea, 21·8°; temperature of the air, 21·2°; fine weather. *Cyanometer*, 22·4°. *Hygrometer*, 44° Deluc (81·5° Saussure).

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
July 1	17° 57′	33° 11′	Sea, 22·4°; air 24·8°. Wind N. E., moderate; cloudy weather. During the night thick fog, which lowered the thermometer at one in the morning to 21·3°.
2	17 26	35 8	Sea, 22·6°; air, 23°: dull weather; a few squalls. Few variations in the meteorological instruments.
3	16 41	36 31	*Temperature* of the sea, 22·5°. Variations of the instruments:
4	16 19	39 19	Sea, 22·5; air, 22°. *Cyanometer*, 23·5°. Sky very clear. At night, wind N. E. very fresh, followed by squalls, and electric rain.

July 2:

Hours	Centig. therm.	Deluc's hygrom.	
1 aftern.	22·7°	51°	(86 Saus.)
2	22·9	51·2	raw weather but without rain; wind N. E., feeble.
4	23·0	51·2	
5	22·9	53·2	
9 evening	22·2	55·2	
10	22·2	57	(89° Saus.)

July 3:

hrs.	ther.	Deluc's hygrom.	
17	22·7°	56·8	(88·7° Saus.) dull.
18	22·6	57·0	Sun rising, very soft rain
20	22·6	56·2	dull.
0	22·8	56·0	very soft rain, scattered drops, which do not touch the hygrometer, and scarcely any way affect the hygroscopical state of the air.
1	22·8	59·0	
2	23·1	59·5	
3	22·7	62·0	
6	21·8	60·2	
11	22·7	57·0	blue, stars beautiful.

<table>
<tr><th>Days of the month.</th><th>North lat.</th><th>West long.</th><th>PHYSICAL OBSERVATIONS.</th></tr>
<tr><td>July 4</td><td>16° 19′</td><td>39° 19′</td><td>Thermometer, the whole day, between 22° and 23·6° ; hygrometer between 87° and 89·6°, Saussure's division.</td></tr>
<tr><td>5</td><td>15 18</td><td>42 21</td><td>Sea, 23·0° ; air 22·2°.
Variations of the meteorological instruments :
<table>
<tr><th>hours.</th><th>Centig. therm.</th><th>Deluc's hygrom.</th></tr>
<tr><td>at 23</td><td>21·9°</td><td>61·2°</td></tr>
<tr><td>0</td><td>23·2</td><td>61·5</td></tr>
<tr><td>2</td><td>23·4</td><td>60·0</td></tr>
<tr><td>3</td><td>23·4</td><td>61·2</td></tr>
<tr><td>6</td><td>23·1</td><td>63·0</td></tr>
<tr><td>12</td><td>23·3</td><td>63·4</td></tr>
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Dull and cloudy weather.</td></tr>
<tr><td>6</td><td>14 57</td><td>44 40</td><td>Temperature of the Ocean, 23·7°; temp. of the air, 22·8°.
<table>
<tr><th>Hrs.</th><th>Therm.</th><th>Deluc's hygrom.</th><th></th></tr>
<tr><td>15</td><td>22·6°</td><td>68·5°</td><td rowspan="7">Dull and cloudy weather.</td></tr>
<tr><td>18</td><td>22·7</td><td>66·5</td></tr>
<tr><td>20</td><td>23·3</td><td>65·5</td></tr>
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</table>
Saussure's hygrometer would have remained between 92·8° and 94·4°.</td></tr>
<tr><td>7</td><td>14 20</td><td>47 38</td><td>In the midst of the ocean between Africa and South America, easter-</td></tr>
</table>

Days of the month.	North lat	West long.	PHYSICAL OBSERVATIONS.
July 7	14° 20′	47° 38′	ly wind very brisk, sky slightly dull; sea very fine. Hrs. Therm. Deluc's hygrom. 14 23·7° 64·5° (92·4° Sauss.) 18 22·6 62·0 20 23·3 61 0 24·4 58·5 4 24·2 56·0 (88·3° Sauss.) 8 23·8 57·2 11 23·6 61·0 *Cyanometer* at 0^h 30′, the sky being without vapors, 32·5°. *Dip* of the magnetic needle 56·30°; oscillations, 239; good observation (latitude 14° 15′ and long. 48° 3′).
8	13 51	49 43	*Temperature* of the ocean, 24·7°; temp. of the air, 23·6°. *Cyanometer* only 17°, and yet the sky perfectly blue, without clouds or visible vapours: blue color of the ocean, 33°. Fine breeze, sea beautiful, at 200 leagues distance from French Guyana to the N. N. E. Hrs. Therm. Deluc's hygrom. 20 23·5° 58° 2 23·0 57 4 23·0 56·2 (88·3° Sauss.) 7 22·8 59·0 12 22·3 62·2 (91·4 Sauss.)

<table>
<tr><th>Days of the month.</th><th>North lat.</th><th>West long.</th><th>PHYSICAL OBSERVATIONS.</th></tr>
<tr><td>July 9</td><td>13° 2′</td><td>52° 53′</td><td>Sea rough. Pretty strong breeze.
Dip of the magnetic needle, 50·67° : good.
Oscillations, 234 ; a little doubtful.</td></tr>
<tr><td>10</td><td>12 34</td><td>54 19</td><td>Fine breeze, very clear sky.
Cyanometer only 16° ; color of the sea 35°.
Temperature of the air from 17^h to 10^h between 24·6° and 23·8°.
Hygrometer, during this time, between 88·5° and 90° Saussure.</td></tr>
<tr><td>11</td><td>11 17</td><td>57 47</td><td>Fine weather, light wind.
<table>
<tr><th>Hours.</th><th>Centig. therm.</th><th>Deluc's hygrom.</th></tr>
<tr><td>18</td><td>24·2°</td><td>60°</td></tr>
<tr><td>20</td><td>24·8</td><td>59</td></tr>
<tr><td>21</td><td>25·2</td><td>58·3</td></tr>
<tr><td>23</td><td>25·0</td><td>59</td></tr>
<tr><td>0</td><td>25·2</td><td>58·5</td></tr>
<tr><td>2</td><td>26·6</td><td>57</td></tr>
<tr><td>8</td><td>25·0</td><td>60</td></tr>
<tr><td>11</td><td>23·7</td><td>58</td></tr>
</table>
Hygrometer of Saussure constantly between 89° and 90·7° ; on the meridian of Surinam, at 80 leagues distance from the Orinoco and from Barbadoes ; during the night a little rain and a beautiful lunar rainbow.</td></tr>
</table>

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
July 12	10° 46′	60° 54′	A smart breeze, particularly during the night; wind east, pretty strong; sea rough; very fine sky, not free from vapours. *Temperature* of the ocean, 25·8°; temp. of the air, 25·3°. *Cyanometer*, 14·4°. Saussure's *hygrometer*, the whole day, from 89·5° to 90·°. *Dip* of the magnetic needle, 46·95°; oscillations, 229 (good observation).
13	11 16	62 45	Cloudy, with squalls; very strong east wind; very high sea; a little rain: distance one league east-south-east of the north cape of the island of Tobago. *Temperature* of the ocean, 25·8°; temp. of the air, 25·1°. *Hygrometer*, from 90° to 91·8° (Saussure's division).
14	11 1	64 51	*Temperature* of the ocean, 25·6°; but on the shoal, which extends from the island of Tobago to that of Grenada, 23·1°; temp. of the air, 25°. Saussure's *hygrometer* 91·5° to 92·7°. *Dip* of the magnetic needle, 47·5°; oscillations, 237; good observation. The mountainous coast of Paria seen at 4 leagues distance: slight breeze; fine and serene weather.

Days of the month.	North lat.	West long.	PHYSICAL OBSERVATIONS.
July 15	10° 51′	66° 12′	Wind north-east, feeble; fair; sea very fine. *Temperature* of the ocean, on the shoal near Punta Araya, 23·4°; open sea, 25·2°; and at five miles distance N. N. E. of the port of Cumana the temperature of the surface of the ocean was only 22·2°, though we had no bottom at sixty fathoms depth. Is this cold owing to the current, that comes from the shoals of the island of Margaretta? In very narrow seas, for instance in the Baltic, the temperature of the water changes also very suddenly. In the port of Cumana, the water of the sea kept in 1799 and 1800 constantly between 25 and 26 degrees, the temperature at low water being often 0·8° higher than at high water. *Temperature* of the air, 28·7°. *Hygrometer*, 86° Saussure.
16	10 28	66 30	Arrived at the port of Cumana.

Determination of the heigths of several points in the island of Teneriffe.

I shall, in this dissertation, discuss the trigonometrical and barometrical measurements, made within the last century, by various travellers, who have visited the island of Teneriffe; and at the same time give an historical sketch of the attempts, which have been made to ascertain the height of the Peak of Teyde, and of the most remarkable points on the road leading to the top of this volcano. It is highly interesting, not to the science of geology alone, to know with precision the absolute height of this mountain; this knowledge is also necessary to perfect the charts of the Canary Islands, because Messrs. de Borda and Varela, at the time of the voyage of the frigate la Boussole, made use of the vertical angles of the Peak and the azimuths, to ascertain the relative distances of Teneriffe, Gomera, and Palma.

Although as early as the year 1648, the experiments of Pascal and Perrier had proved, that the barometer might be successfully applied to measures of height, it is however only since the beginning of the 18th century, that we have accurate ideas of the elevation of a few mountains. Riccoli still gave ten Italian miles, and Nichols fifteen leagues of height to the Peak

of Teyde*. Eden did not attempt to measure the height, though he reached the summit of the volcano in 1715. His voyage† however, the earliest that was published, fixed the attention of the geographers and natural philosophers of Europe; and the first attempt at measuring the height of the Peak was made by P. Feuillée‡ in 1724. This traveller found by trigonometrical measurement the absolute height to be 2213 toises. La Caille, speaking of this measurement in the Memoirs of the Academy§, expressed his doubts of the accuracy of the result. These doubts have been revived by Bouguer; who, in fixing the limits of the perpetual snows under different zones, has examined with his usual sagacity P. Feuillée's operations; and he concludes, that the height of the Peak does not exceed 2062 toises‖.

* Zach, Journ. Astron., 1800, t. i, p. 396. Vieyra, Noticias Historicas, t. i, p. 234.

† Phil. Trans., vol xxvii, p. 317.

‡ Manuscript Journal of Pére Feuillée.

§ Mém. de l'Académie, 1746, p. 143. Voy. de la Flore, t. i, p. 114.

‖ Fig. de la Terre, p. 48. Deluc, Rech. sur les Mod. de l'Atmosphère, § 280 and 763. Notwithstanding the examination of Bouguer, and the well known measurement of Borda, we still find, in several physical works, the height of the Peak estimated at 2097, 2160, and 2270 toises. *See* the third edition of Marsden's valuable History of Sumatra, published in 1811, p. 14; and Breislack's Geology, t. i, p. 6, in which work the table of heights swarms with typographical errors.

There exists also another measurement of this mountain, made during the voyage of P. Feuillée by M. Verguin. This measurement, merely barometrical, has been hitherto neglected; because, having been calculated according to the method of Cassini, it had given the excesssive height of 2624 toises *. This error, which exceeds two fifths of the total height of the volcano, will be reduced to one twentieth, if the method of Laplace, and the coefficient of Ramond, be applied to the observations of M. Verguin; and if we suppose, what is probable enough in a latitude so southerly, that the pressure of the air did not very sensibly change in the space of three days. On the 31st of July, 1724, P. Feuillée's barometer, at the Port of Orotava, stood at 27 inches, 9·7 lines. On the 3d of August the same instrument was found on Monte Verde at 23 inches, 0 lines, and at the top of the Peak at 17 inches, 5 lines. P. Feuillée mentions neither the temperature of the air at the two stations, nor the correspondent observations made at the same hours on the coast. Travellers themselves, at that time, constructed their barometers on the spot; and meteorological instruments were utterly unknown at Orotava and at Santa Cruz. The observation on the top of the volcano having been made in a season when

* Mém. de l'Académie, 1733, p. 45.

the variation of the barometer, on the coasts of Teneriffe, seldom exceed in the space of three days one or two lines, we may, in calculating the height of the Peak, take for our basis the height of the mercury observed on the 31st of July. Supposing twenty-two centesimal degrees for the temperature of the coast several hours before the Sun passed the meridian, and five degrees for the temperature of the air at the top of the volcano, which is conformable to the law of decrement of heat in those regions; I find, by Mr. Laplace's method, two thousand and twenty five toises, or one hundred and twenty toises more than is given by the trigonometric measurement of M. de Borda. Whatever alteration we make in the estimation of the temperature, and of the barometrical height at Orotava, it will still be found, and this fact is very remarkable, that the barometric measurement of M. Verguin is much more accurate than the geometric measurement of P. Feuillée. The error of the latter, in which the level of the ground employed for the measurement of the base was neglected, is almost three times as great as the error of the barometric measurement, which we have just stated.

The observations, which P. Feuillée made at the town of Laguna, indicate nearly the absolute height of this place, so well known for its great coolness. Taking the barometrical average of two months, during which the extreme deviations

amounted only to four or five lines, we find at Laguna 25 inches, 11 lines, and at the port of Orotava 27 inches, 10 lines. Now, supposing the temperatures of these two stations at fifteen and twenty degrees of Reaumur's thermometer, I obtain by Laplace's method, three hundred and thirteen toises for the town of Laguna. This height would be augmented only sixty-six toises, or one fifth, if 28 inches 3 lines were taken for the mean height of the column of mercury at the port of Orotava; though it is well known, that P. Feuillée's barometer, by no means well freed from air, was constantly six or eight lines, or even more, too low*. Mr. Lichtenstein, who has made an interesting journey into the interior of Africa, reckons the absolute height of Laguna two or three thousand feet above the level of the coasts †.

Adanson, in his voyage to Senegal ‡, states, "that the elevation of the Peak of Teyde (in 1749) was found to be more than two thousand toises." It is probable that this result was founded on a base measured by the log, and or an operation made under sail by M. Daprès de

* Feuillée's barometer at the top of the Peak, 17 inches 5 lines. Borda's barometer at the same point, 18 inches 0 lines. Lamanon's barometer, 18 inches 4 lines.

† Allgem. Geog. Ephemer. 1806, p. 51.

‡ Vol. i, p. 8.

Mannevilette, commander of the vessel which Adanson was on board.

Dr. Heberden*, in the narrative of his excursion to the top of the Peak in 1752, says he found the absolute elevation of the volcano to be 15396 English feet, or 2408 toises. "This result," adds he, "has been confirmed by two other operations, which I have successively executed: it is also entirely conformable to the results of two trigonometrical operations made long before by Mr. John Cross, English consul at Santa Cruz in Teneriffe." Here are five measurements, which it is stated agree perfectly well with each other, and in which there is an error of more than five hundred toises, or a fourth part of the total height of the Peak. Dr. Heberden lived seven years at Orotava; we must regret, that he enters into no detail on the nature of the instruments employed by him and Mr. Cross, or the values of the angles, or the length and levelling of the base, on which the triangles repose. The whole of these operations, which we have just mentioned, deserve no more credit than those of Don Manuel Hernandez†; who asserts, that he found, in 1742, by geometrical measurement, the height of

* Phil. Trans. vol. xlvii, p. 353. Cook's second Voyage round the World, vol. ii, p. 282. Barrow, Voyage à la Cochin Chine, t. i, p. 69.

† Borda, Voyage de la Flore, t. i, p. 88.

the volcano to be 2658 toises, and consequently 200 toises higher than Mount Blanc.

We are indebted to Borda for the knowledge of the real elevation of the volcano of Teneriffe. This excellent geometrician obtained an exact result after having fallen into an error, which he attributes to the negligence of one of his coadjutors. He took three measurements of the Peak; two geometrical, and one barometrical. The first geometrical measurement *, executed in 1771, gave only 1742 toises; and as long as it was considered as accurate, Borda and Pingré found, by operations made under sail, the height of the Peak 1701 toises †. Happily Borda visited the Canary Islands a second time, in 1776, conjointly with Mr. de Chastenet de Puységur; and he then executed a more accurate trigonometrical measurement, of which he published the result only in his Supplement to the Voyage of the Flora ‡. We there find "that the principal cause of the error committed in 1771 had been a mistake in the indication of an angle, minuted in the regisgister as being thirty-three minutes, while it was in reality found to be fifty-three minutes."

The result of the trigonometrical measurement

* Borda, Voy. de la Flore, t. i, p. 89.

† "All the parts of our work reciprocally confirmed each other, and concurred in the same determination." Ibid., t. i, p. 120. Journ. de Phys. 1776, p. 66; and 1779, p. 129.

‡ Vol. i, p. 378.

made in 1776 is 1905 toises; it is this which is now most generally adopted, and on which is in great part founded the position of the Canary Islands, in Varela's and de Borda's charts. I trust, that I shall render a service to naturalists, philosophers, and navigators, in here recording the detail of the operations made during the voyage of the frigate la Boussole, and taken from the valuable manuscript which I mentioned in the preceding chapter*. It were to be wished, that M. de Borda's Journal was published entire. The results it contains are found in the *Carte particulière des Isles Canaries, d'après les Observations de la Boussole et de l'Espiégle*, 1776. This chart, the best of all that have hitherto appeared, forms a part of the collection published by the Dépôt of the Marine, at Paris.

"The measurement of the Peak of Teneriffe," says M. de Borda, "was not an object of mere curiosity, but was essentially connected with our nautical labors. It was necessary for us to know the exact height of this volcano, in order to avail ourselves of the observations of apparent height which we had made at several points of the island of Teneriffe, Gomera †, and Canary, and which

* Vol. i, p. 140. The manuscript of the Dépôt is 190 pages in 4to; it was copied from the original, by M. de Fleurieu. I am indebted for the communication of it to the kindness of Viceadmiral Rosily.

† At the port of Gomera, for instance, M. de Borda

were to serve for ascertaining the longitudes and latitudes of those points.

"The ground in the neighbourhood of the port of Orotava being unequal, and intersected with vales, it was not possible for us to find a base extensive enough to determine the distance of the Peak by a single triangle, and we employed three. We measured near La Paz, a country house of Mr. Cologan, our first basis*, *a b*, of 229·5 toises; by means of this we calculated a second, *a c*, of 614 toises; and afterward a third, *c d*, of 1526 toises. The point *c* was the summit of the hill, called by the natives the *Montanne del Puerto*, which commands the town of Orotava. The station *d* is the western extremity of a gallery of the house of Colonel Franqui, at the villa del Orotava, near the dragon-tree so celebrated for its size and age. It appears that the base of P. Feuillée had been measured on a plain sufficiently large, but not horizontal, at the foot of the hill of la Paz, near Mr. Cologan's country house. Our base *a b* was measured successively by two different parties: the first found it 1377 feet 6 inches, the second 1377 feet, 3 inches, 6 lines. Both made use of three rods of fifteen feet each,

found the angle of altitude of the Peak 4° 1′. An azimuth placed the mountain East 24° 17′ north. Supposing its elevation above the level of the ocean 1904 toises, we find the port of Gomera distant from the Peak 0° 27′ 18″.

* See Plate 1.

carefully measured by a three foot rule, which M. Varela had compared at Cadiz with the Peruvian toise of Mr. Godin. The following were the angles taken with a quadrant of a foot radius, made by Ramsden.

Triangle $a\ b\ c$	Triangle $a\ c\ d$.	Triangle $c\ P\ d$
$b\ a\ c = 85° 53' 55''$	$d\ a\ c = 85° 58' 40''$	$c\ d\ P = 94°\ 0'\ 40''$
$a\ b\ c = 73\ \ 8\ \ 55$	$d\ c\ a = 70\ \ 20\ \ 55$	$d\ c\ P = 76\ \ 34\ \ 0$
$b\ c\ a = 20\ \ 57\ \ 15$	$a\ d\ c = 23\ \ 40\ \ 8$	
$180\ \ 0\ \ 5$	$179\ \ 59\ \ 43$	

We measured the three angles of the triangles $a\ b\ c$ and $a\ c\ d$. As in the triangle $c\ P\ d$ this kind of verification could not be employed, I measured with the greatest exactness the two angles $c\ d\ P$, and $d\ c\ P$, by means of a reflecting circle; and I found only from 8 to 10 seconds of difference. Hence it follows, that the angle at the Peak, $d\ P\ c$, is 9° 25′ 20″. We find also $a\ c$ = 3686·2 feet; $a\ d$ = 8647·3 feet; $c\ d$ = 9159·5 feet; $c\ P$ = 55814·6 feet; and $d\ P$ = 54420·9 feet. The vertical angles give the following heights of the Peak, or of the different stations from one another. Altitude of the Peak seen from point d, = 10423·2 feet; the same seen from the point c, = 11116 feet; that of the point d above the point a, = 733·6 feet; the same above the point c = 687·6 feet; and that of the point c above the point a = 47·3 feet. From these data, the height

		Feet.
of the Peak above the point d being	.	10423·2
if we add the height of the point d above the point a . . .		733·6
we have a first height of the Peak above the point a . . .	.	11156·8
In the same manner, that of the Peak above the point c being	.	11116·0
If we add that of the point c above the point a . . .	.	47·3
we have a second height of the Peak above the point a . .	.	11163·2

Taking the mean of these two results, we find 11160 feet; and on deducting for the effect of the refraction 13·7 feet, we have 11146·3 feet. It now remains to determine the height of the point a above the level of the Ocean. The depression of the horizon of the sea, at a, was 17′ 77″, and at d, 32′ 25″. According to these depressions, the point a is raised above the level of the Ocean 283·6 feet; and on adding this quantity to the height of the Peak* above the point

* M. de Borda had found, on his first calculation, 1904 toises, assuming nineteen feet for the effect of the refraction. He has not indicated the apparent altitudes; but we may deduce them from the values of d P and c P. At c the Peak must have subtended a vertical angle of 11° 29′ 18″. A slight error appears in the altitudes of d above c, and of c above a. At the port of Orotava, at the house of Mr. Cologan, the apparent altitude of the volcano was found to be 11° 29′ 35″. An azimuth gave for the position South 29° 44′ West, whence results a distance of 0° 9′ 45″.

a, we have 11430 feet absolute height, or 1905 toises."

The third measurement made by M. de Borda was a barometrical one. We have extracted the following details also from the Manuscript of the Dépôt, and find them nearly agreeing with the results published by Mr. Cavanilles in 1799, from the Manuscript of Don Jose Varela in the *Anales de Ciencias naturales* *. "M. de Borda left Santa Cruz the 27th of September, 1776. He was accompanied by forty persons, among whom were eleven officers of the French and Spanish navy. They were provided with variation compasses and dipping needles, a time-keeper, several thermometers, and two excellent barometers, which had been compared, at the port of Orotava, with the barometer of Mr. Pasley, a Scotch merchant †. On their return from the Peak, these instruments were verified anew; the difference remained absolutely the same, and by the interpolation of a great number of observations made hourly by Mr. Pasley, the following differences were found:

* T. i, p. 295. I know not from what misunderstanding it is asserted, in this same work (t. i, p. 85), that I had found the height of the Peak 1917 toises.

† Mr. Pasley declared, that he had not observed, for several years, Reaumur's thermometer, at the port of Orotava, above 22·7°, or below 12·5°.

Stations.	Barometers.				Ther. in the air. Scale of Reaum.	Remarks.
	inches.	lines.	inches.	lines.		
Pino del Dornajito Port of Orotava	25 28	1·4 2·8			16° 20	
Station of the Rocks Port . . .	19 28	9·5 2·7	19 28	9·8 3·0	8 19·5	Eight in the evening.
Cavern of ice . . Port . . .	18 28	9·2 2·8			10 19	Twenty minutes after seven in the morning.
Foot of the Piton . Port . . .	18 28	4·5 2·3			9 19·5	Half after eight in the morning.
Summit of the Peak . Port . . .	18 28	0·0 2·8	18 28	0·4 3·0	8·5 20·0	Half after ten in the morning.

"From eight in the evening of the 30th of September, to half after ten in the morning, of the first of October, the barometer had varied only 0·2 of a line. According to the barometric method of Deluc*, we find the following heights, adding 11 toises for the elevation of Mr. Pasley's house above the level of the sea: Pino del Dornajito, 516 toises; Station of the Rocks, 1518 toises; Cavern of Ice, 1757 toises; foot of the Piton, 1847 toises; Summit of the Peak, 1929 toises."

I have recalculated M. de Borda's observations, conjointly with M. Matthieu, after the method of M. Laplace; and, supposing the temperature of mercury equal to that of the air, and reducing the station to the level of the sea, we obtained for the Pino del Dornajito 533 toises; for the Estancia de los Ingleses, 1555 toises; for the Cavern of Ice, 1799 toises; for the Foot of the Piton, 1892 toises; for the Top of the Volcano, 1976 toises. This last result differs from that of the trigonometrical measurement twice as much as the height obtained by the formula of Deluc. We shall discuss farther on the causes of error, that may have affected the particular operations.

It commonly happens, when the application

* Compare Fleurieu in Marchand's Voyage, t. ii, p. 11. Forster (Observat. during a Voy. round the World, vol. i, p. 22) allows the Peak 12340 english feet, or 1931 toises, from Borda's barometrical measurement.

of small corrections to barometrical and thermometrical heights is in question, that travellers, who have made observations together, do not fix on the same numbers, as means of good observations.

Messrs. Varela and Arguedas give, in their memoir on the measurement of the Peak, the following barometrical heights:

	inch.	lin.	
1. Pino del Dornajito	25	0·86	Th. 17° R.
Level of the Sea	28	4·00	$19\frac{1}{6}$
2. Estacion de los Ingleses	19	9·81	9
Level of the Sea	28	3·72	$19\frac{1}{2}$
3. Cueva de la Nieva	18	8·93	$11\frac{1}{8}$
Level of the Sea	28	3·51	$18\frac{1}{3}$
4. Foot of the Sugar Loaf	18	3·89	$9\frac{1}{2}$
Level of the Sea	28	3·51	$19\frac{1}{20}$
5. Top of the Peak	18	0·11	$8\frac{1}{2}$
Level of the Sea	28	3·72	$19\frac{1}{10}$

Mr. Varela finds, I know not after what formula, 534 toises for the first station, 1531 toises for the second station, 1780 toises for the third station, 1864 toises for the fourth station, and 1940 for the fifth station. The small differences which may be observed between the barometrical heights indicated

by the Spanish navigators, and those laid down by M. de Borda, arise in a great measure from the one being reduced to the level of the sea, while the others refer to the height of the ground where stands Mr. Pasley's house.

At the time of La Pérouse's Voyage in 1785, M. Lamanon carried a barometer to the top of the Peak of Teneriffe. The observation of this naturalist *, calculated by Mr. von Zach, gives, by Mr. Deluc's method, 1856 toises; by that of Sir G. Shuckburgh, 1893 toises and by that of Roy, 1889 toises. The result of the same barometric observation, according to M. Laplace's formula, is 1902 toises.

Mr. Johnstone, measuring a base by means of the log, found the height of the Peak to be 2023 toises †. M. de Churruca in a voyage to the Straits of Magellan, made in 1788, attempted also to determine the height of the volcano, by a geometrical operation while under sail ‡. He found it 2193 toises, " congratulating himself on having attained a greater exactness than could

* See Vol. I, p. 185, Zach. Journ. Astron., 1800, p. 396. We are susprised to see, that, at a time when the useful labors of Deluc, Shuckburgh, and Tremblay, on the barometic formulas, had long been known, the editor of La Pérouse's voyage (t. ii, p. 18) should have expressed so many doubts of the results obtained by the barometer.

† Lord Macartney's Voyage, t. i, p. 158.

‡ Viage al Magellanes, Apendice, p. 10.

reasonably have been expected *(toda esperanza racional)*, since the barometrical heights calculated by Bezout* gave the same number of toises." It is the same with the measurement of mountains, as with the determinations of latitudes and longitudes. The observers are satisfied with their operations, when they find them agree with some old results, to which they give the preference above all others.

M. Cordier measured the Peak on the 16th of April, 1803, employing Mossy's barometer, which he had boiled the preceding evening, and in very fine and settled weather, which lasted a month. "The instruments were placed to the windward of the Peak, and the barometric height was brought to the temperature of the ambient air. The correspondent barometer, of English construction, differed only $\frac{7}{10}$ of a line, ancient French measure, from that of Mossy employed by the traveller. Though the persons appointed to make the observations at Orotava, Messrs. Little and Legros, did not employ the nonius, they estimated nevertheless the heights of the mercury with great exactness to fourths or fifths of a line†." M. Cordier took account of the small changes of level in the cistern; and being

* Cours de Mathématiques, vol. iv, p. 416 (edit. de 1775.)

† These particulars and barometrical heights, which were not printed in the Journal de Physique, t. lvii, p. 60, have

well accustomed to barometric measurements, employed every necessary precaution, to obtain an accurate result. The following is the table of his observations.

TABLE.

Stations.	Hours.	Barometer.	Reaum. Therm.
		inch. lines.	
Estancia de los Ingleses	$4\frac{1}{2}$	19 9·5	4·9°
Port of Orotava		28 4·6	15·0
Summit of the Peak	the morn.	18 4·0	6·7
Port of Orotava		28 5·6	19·9

The corresponding barometer was placed at the height of seven toises above the level of the sea. M. Cordier found by Deluc's formula the Station of the Rocks to be 1529 toises, and the top of the volcano 1901 toises. M. Laplace's formula gave me for the first of these points 1550 toises; and 1920 toises * for the second.

been communicated to me by M. Cordier. This traveller, who has visited Egypt, Spain, and the Canary Islands, is preparing an interesting work on extinct Volcanoes.

* In the manuscript voyage of Mr. O'Donnell, for the communication of which I am indebted to the kindness of M. Leudé de Segrai, is the following note: "The barometric measurements which we made of the height of the volcano nearly coincide *(con corta differencia)* with those of

Let us now resume the barometrical and geometrical measurements of the Peak made for a century past.

1. Geometrical measurements.
a) made on land.

	toises.
P. Feuillée, in 1724	2213
the same result modified by Bouguer	2062
Heberden and Cross, five operations, in 1752	2408
Hernandez, in 1742	2658
Borda and Pingré, in 1771	1742
Borda, in 1776	1905
b) made under sail.	
Mannevilette, in 1749	2000
Borda and Pingré, in 1771	1701
Churruca, in 1788	2193
Johnstone, ...	2023

2. Barometric measurements calculated after the formula of La Place.

	toises.
Feuillée and Verguin, in 1724 . . .	2025

M. Cordier, paying attention to the difference between the French and Spanish toises, absolute height of the ravines at the foot of the Peak 1278 Spanish toises; Estancia de los Ingleses, 1731 toises; summit of the Peak 3287 toises." I cannot guess what Mr. O'Donnell calls Spanish toises; for supposing him to mean the *vara castellana*, 2·23 of which make a French toise, the volcano would be much less elevated than M. de Borda found it, even in the first of his three measurements.

	toises
Borda, in 1776	1976
Lamanon, in 1785	1902
Cordier, in 1803	1920

These measures, taken at different periods, vary from 1700 to 2600 toises; and, what is remarkable enough, the results obtained by geometrical operations differ more from each other, than those which were found by the barometer. It has nevertheless been extremely wrong to cite this want of harmony as a proof of the uncertainty of all measurements of mountains. Angles, the value of which is determined by imperfect graphometers; bases that have not been levelled, or the length of which has been determined by the log; triangles that give an excessively acute angle at the summit of the mountain; heights of the barometer without any notice taken of the temperature of the air and of the mercury; unquestionably are not means calculated to lead to accurate results. Of fourteen trigonometrical and barometrical operations above indicated, the four following only can be considered as true measurements.

	toises.
Borda by trigonometry . . .	1905
Borda by means of the barometer .	1976
Lamanon, the same . . .	1902
Cordier, the same	1920

The average of these four observations, the

whole of the particulars of which are known to us, makes the absolute height of the Volcano 1926 toises; but we must here discuss the question, whether, in taking the mean, we ought to exclude Borda's barometric measurement, as erring too much in excess; or whether we ought not to prefer the result of the trigonometrical to that of the barometric measurements of a Peak, almost continually swept by ascending or descending winds.

The trigonometrical operation, made in 1776, is more complicated than those generally are, by which we determine the elevation of a single point. Travellers are in the practice of employing either a base directed toward the summit of a mountain, and two vertical angles taken at the extremity of this base, or rather a base nearly perpendicular to the former, two angles of position taken in an oblique plane, and a single vertical angle. In both cases a direct measure is taken of a side of the triangle, the summit of which is at the top of the mountain. The measurement of the Peak executed by M. de Borda was a trigonometrical operation precisely similar to those, by which, in the measurement of a meridian, the heights of signals, or of mountains near those signals, above the level of the sea, is determined. It cannot be denied, that the simplicity of a method, and the small number of the elements entering into

the calculation of the altitude, offer peculiar advantages; but it would be unjust to condemn more complicated operations, if we could be assured, that the observers had taken the greatest care in the resolution of each triangle.

M. de Borda could not directly measure the great base of 1526 toises, at the extremities of which he determined the oblique angles of position, and the vertical angles that subtend the height of the volcano. The length of this base was found by the resolution of two small triangles; and this determination deserves so much the more confidence, as all the angles were directly measured, as the result obtained by a small quadrant of Ramsden was verified by a reflecting circle, as the errors of each angle do not appear to have exceeded eight or ten seconds, and as the first base of 213 toises was measured twice, without finding more than two inches and a half difference. I do not believe, that this part of M. de Borda's measurement can have been deficient in accuracy; and it must be hoped, that the same precision was attained in the vertical angles, three of which were indispensable for the measure of the Peak; namely the summit of the Piton seen at *d*, the signal *d* seen at *a*, and the depression of the horizon of the sea. It might have been wished, that the observer had determined these angles by means of his reflecting circle, employing as an artifical

horizon a plane glass, or mercury *; for the error of the line of collimation and the horizontal position of the instrument are very difficult to determine with exactness in a movable quadrant of a foot radius. According to the manuscript kept in the Depôt de la Marine, this verification of the vertical angles did not take place; and the accordance of the two altitudes of the Piton above the points *d* and *e* is a proof rather of the constancy of the error of collimation, than of the precision of the absolute value of the angles. In order to have obtained two comparative results, M. de Borda should have taken seven zenith distances; that of the summit seen at *c* and at *d*, that of the signal *d* seen at *a* and at *e*, that of the signal *c* seen at *a*, and the depressions of the horizon of the sea measured at *d* and at *a*. It is well known, that these zenith distances are more difficult to obtain with exactness than the oblique angles of position, especially when we cannot make use of an astronomical circle of repetition. Farther, in similar circumstances, a method is so much the more disadvantageous, as

* I have shown in another place, that, on the seashore, we can measure with great exactness the depression of the horizon with a reflecting instrument, by taking alternately the height of the Sun above the horizon of the sea, and in an artificial horizon, and reducing these heights to the same instant.

the vertical angles are more numerous. To solve the question, what is the number of toises by which the height of the Peak may have been found too great, or too little, I have supposed an error in the measure of the base, in that of the vertical angle subtended by the mountain, and in the terrestrial refractions. If the volcano be 1925 toises of absolute height, instead of 1905 toises, the angle of P at c would be, according to Mr. Oltmann's calculation and mine, 10° 36′ 34″, instead of 11° 29′ 18″, found by M. de Borda; the bases $c\ d$ and $a\ b$ would be 9258 and 1392 feet, instead of 9159 and 1278. But how can it be supposed, that he was deceived 7′ 16″ in determining the error of collimation of the quadrant, and fourteen feet in the double measurement of a base of 229·5 toises? We are ignorant at how much M. de Borda estimated the effect of the terrestrial refraction; but it is probable, that his supposition did not much differ from one tenth of the arc. The distance of the volcano is nine miles, and a variation of refraction of 22″ would change the total height of the mountain but one toise.

As bases adapted to the measurement of mountains are not generally to be found on a coast, and at the level of the Ocean, travellers are forced to recur, either to barometrical measurements, or to the depression of the horizon. In M. de Borda's operation, these reductions have been pretty

considerable, *d* being elevated 169 toises, and *c* 55 toises above the surface of the sea. But when the subject of discussion is the comparing barometrical and geometrical measurements, which differ but a small number of toises, we must examine, what is the limit of the mistakes that may be committed, and whether the measure be too great or too little. The variations of the terrestrial refraction elevate or depress the horizon of the sea two or three minutes, to an observer placed on the coast three or four toises high. At this distance the trajectories may be more or less concave or convex, according to the temperature of the land and of the sea, and the unequal decrement of density in the successive strata of the air. In proportion as the observer increases his height above the coast, the mistakes owing to the irregular variation of the refractions diminish considerably; and it is easy to show, that at the time of M. de Borda's operation they did not exceed three or four toises*. As the sea at this period was colder than the air, the stations *c* and *d* may have been found lower than they really are †; and we

* The numerous observations of depression made by Mr. Méchain at Montjouy, near Barcelona, differ from each other but $7\frac{1}{4}$ toises, the total height of the mountain being 105 toises. Delambre, Base du Système métrique, t. ii, p. 759 and 765.

† Biot, on extraordinary refractions, in the Mém. de l'Institut, 1809, p. 157, 177, and 180. M. de Borda, like the

may suppose, what is confirmed by barometrical measurement, that the trigonometrical result obtained in 1776 is rather too small than too great.

On resuming what has just been laid down from examining in succession the different elements, that enter into the calculation of the absolute elevation of the Peak of Teneriffe, it follows, that the trigonometrical measurement made by M. de Borda is probably exact at least to $\frac{1}{316}$ of the total height; unless we suppose accidental mistakes, owing to the negligence of the observers.

I have no doubt but the same degree of exactness may be obtained in very favourable circumstances from repeated measurements made by the barometer; but it is difficult to judge, amidst a few isolated observations, whether oblique winds, or an unequal distribution of heat in the succes-

greater part of those geometricians who have measured the depression of the horizon, has neglected to indicate the temperature of the ocean: but we know that at this period the air was at 25 degrees, and from the observations already made, page 65—79, we may admit, that the heat of the water of the sea was from 20 to 21 degrees. Now, heights of thirty toises, calculated on the supposition of a mean refraction of 0·08, and of a uniform decrement in arithmetical progression, appear diminished three toises when there are four degrees of difference between the temperature of the air and the water. This number is deduced from the numerous observations made by Messrs. Biot and Mathieu at Dunkirk.

sive strata of the air, have not altered the results. Of three barometric measurements made by M. M. de Borda, Lamanon, and Cordier, and calculated after the formula of Laplace, and the coefficient of Ramond, there is only the second which does not give a greater height than the geometrical operations. If Deluc's or Trembley's formula be substituted for that of Laplace, the heights, instead of being too great, will be too little. Supposing the Peak to be really 1905 toises high, Laplace's formula, applied to M. M. Lamanon and Cordier's observations, would be erroneous only $5\frac{1}{2}$ toises, or $\frac{1}{346}$; an extremely small quantity, and which would be the half or the third only of that, to which excellent observers may be often exposed *.

The first coefficient † of the barometric formula

* Mr. D'Aubuisson concluded, after having discussed a great number of observations calculated after the formula of Laplace, and compared with exact geodesical measures, "that in avoiding the manifest causes of inexactness, such as the morning hours, the considerable changes of weather from one day to another, storms, and the influence of localities, we may consider a hundredth as the limit of the mistakes." He adds, that "most commonly, by fortunate compensations, the error will be only some thousandths." Journal de Physique, t. lxxi, p. 35.

† The coefficient, 17972 metres. Exposition du Système du Monde, ed. 1, p. 82. Ramond, Mém. sur la Formule barométrique, p. 2.

of M. de Laplace, published in 1798, was founded on the comparison of the barometrical and geometrical measurement of the volcano of Teneriffe, made by M. de Borda. The illustrious author of *La Mécanique céleste* having afterward found, that this coefficient did not give exact heights, substituted another, furnished by the excellent observations of M. Ramond. On examining the manuscript narrative of Borda's voyage, we can not guess at the source of an error, which seems considerably to surpass that of the barometric measurement of Mount Blanc by Saussure. The corrospondent barometer was observed at Orotava every quarter of an hour; its greatest variations, in twenty-four hours, were a few tenths of a line. The scales were carefully verified; and an account was taken of the accumulation of the mercury in the cistern*. The thermometer was observed in the shade; the slightest circumstances are found indicated in Messrs. de Borda and Varela's journals. They are the only travellers, who have carried two barometers to the top of the Peak. Both instruments agreed within three or four tenths of a line with each other, and the average of both was constantly taken. If we were not acquainted with the real height of the Peak to a considerable degree of exactness, we might pre-

* It was 0·9 of a line on the brink of the crater.

sume, that the barometric measurement taken in 1776 could not be $\frac{1}{100}$ erroneous, while it is probably beyond $\frac{1}{50}$. It is sufficient to compare the indications of Borda's barometer and thermometer with the indications of these same instruments in Lamanon's and Cordier's voyages, to discover, that in the morning of the 1st of October, 1776, on the summit of the Piton, the pressure of the air underwent an extraordinary and very problematic modification. The following are the elements of this comparison.

Places.	Barometer and Reaumur's Thermometer. Borda, 1776. Bar. inch. lines.	Borda, 1776. Ther.	Lamanon, 1785. Bar. inch. lines.	Lamanon, 1785. Ther.	Cordier, 1803. Bar. inch. lines.	Cordier, 1803. Ther.	Height according to Laplace's formula. Toises.	Decrement of caloric; number of toises corresponding to 1° of Reaumur. Toises.
Estancia	19 9·7	8°	. .	.	19 9·5	4·9°	B. 1555	B. 134
de los Ingleses.	28 2·9	19·5	. .	.	28 4·6	15	C. 1543	C. 155
Summit	18 0·2	8·5	18 4·3	9°	18 4·0	6·7	B. 1976	B. 165
of the Peak.	28 2·9	20	28 3·0	24·5	28 5·6	19·9	L. 1902	L. 123
							C. 1920	C. 144

We are struck at seeing in this table, that M. de Borda found his barometer, at the summit of the Peak, four lines lower than other observers; and this, without any indications of the thermometer tending to explain why there was so enormous a difference in the atmospherical pressure *. It might be supposed, that the instruments were deranged during the night, which the travellers passed at the Station of the Rocks; but we find it expressly noted in Messrs. de Borda and Varela's journals, that, the day after the excursion, the difference between Mr. Pasley's barometer at Orotava, and those which had been made use of for the measurement of the Piton, remained the same to nearly two tenths of a line. The volcano of Teneriffe, like all other very slender peaks, is undoubtedly but little adapted to disclose the error of a barometric coefficient. Oblique winds sweep along the rapid declivity of the mountain; and it is to be presumed, that, at the time when M. de Borda measured it, a very violent ascending wind, or some other unknown deranging cause, occasioned the barometer to fall. The weather

* The error of a degree in the indication of the temperature of the air would alter the height of the Peak only 3·8 toises nearly. A considerable number of good observations, made at the top of St. Bernard, prove, that the whole of the calculated elevations are too great or too little, every time that the temperatures are above or below the mean temperature of the two stations. Journ. de Phys., t. lxxi, p. 10.

had been rainy the preceding evening; the decrement of caloric was very slow and probably of very little uniformity; circumstances under which any formula would be at default; but notwithstanding these considerations, without the testimony of an observer so exact as M. de Borda, we should scarcely believe that the barometric pressure could change four lines at a height of more than 1900 toises, and at the limits of the torrid zone. A single barometric measurement is like a longitude determined by the mere difference of time: both, executed with good instruments, and under favorable circumstances, are susceptible of great exactness; but when the meteorological variations, or the rate of the chronometer, are not regular and uniform, it is impossible to fix the limit of the errors, as we may do with success in discussing a geometrical operation, or the result of a series of lunar distances.

After having excluded the barometric measurement of Borda, two others remain, which inspire great confidence, but of which one appears to be somewhat too little, and the other too great. We have already remarked, that their mean result does not differ 0·003 from the geometrical measurement; and we shall not give a preference to the barometric observations of Lamanon over those of M. Cordier, because we think we have proved, that the result even of the trigonometrical

measurement may well be a few toises too small, and M. Cordier made his excursion in very fine and settled weather. This gentleman thinks, that his measurement must have given a result near the truth, on account of the numberless precautions which he took to avoid errors*. The observation was made in the morning; and it is known, that at this time of the day Laplace's formula makes the heights too little, because his coefficient was deduced from observations made at noon; but on the other hand, Mr. Ramond has rendered it probable, that the coefficient appropriate for our northern countries must undergo a slight diminution to adapt it to the measurement of the heights comprised between the tropics, or near the limits of the torrid zone†. A compensation therefore took place: and this compensation was not disturbed by the effects of the diurnal variation of the barometer. I insist on this latter circumstance, because distinguished natural philosophers have recently asserted, that the barometer must sink on high mountains, while at nine in the morning it reaches its maximum in the plains. This assertion ‡ is founded only on theoretical views, and on a local phænomenon observed by Saussure in the Alps. The obser-

* Ramond, p. 5 and 26.

† Ibid, p. 97.

‡ Journ. de Phys., t. lxxi, p. 15.

vations made by M. Bonpland and myself on the horary variations of the barometer, from the coasts to two thousand toises height, prove on the contrary, that, under the tropics, the mercury reaches its maximum and its minimum exactly at the same hours in the low regions and on the summits of the Andes.

The real height of the Peak of Teneriffe differs little probably from the mean between the three geometrical and barometrical measurements of Borda, Lamanon, and Cordier.

1905 toises
1902
1920
———
1909

The exact determination of this point is of importance to the science of physics, on account of the application of the new barometric formulas; to navigation, on account of the angles of altitude, which experienced seamen sometimes take, when they pass in sight of the Peak; and to geography, on account of the use which M. M. Borda and Varela have made of the same angles, in the construction of the chart of the archipelago of the Canaries.

In the second chapter of this work, Vol. i, p. 183, we have entered into the question, whether

the coast of Africa could be seen from the summit of the Peak of Teneriffe. This problem has been discussed by M. Delambre, to whom we are indebted for so great a number of valuable observations on horizontal refractions. The following are the foundations of the calculations, of which we have given only the result, in that chapter. Let *m* (fig. 2) be the Peak of Teneriffe, and N the coast, the distance of which from the foot of the Peak is the arc P T Q $= 2° \; 49' \; 0''$. As refraction makes objects appear higher than they really are, it will be possible to see from the top of the Peak the point N, although it is concealed by the curve of the Earth. This point will be really visible if it be elevated enough to send forth a ray, which, in describing the curve N T M across the strata of the atmosphere, only skims the Earth in T. From the summit of the Peak we should perceive then at once the points T and N, and an observer placed in T would see the points M and N in his horizon N′ T M′. If we designate by $h = 1904$ toises, the height of the Peak, according to the geometrical measurement of Borda; by $R = 3271225$ toises, the radius of the Earth; and finally by c the coefficient of the terrestrial refraction, the mean value of which was found to be 0·08 by Mr. Delambre; we shall have the distance P T, at which the observer ought to be in order to see the summit M, at M′ in the horizon, by the formula,

$$\text{tang. } P\,T = \frac{1}{(1-c)} \sqrt{\frac{2h}{R}}$$

which gives P T = 2° 7′ 26″. Such is the greatest distance at which we can perceive the Peak from the level of the sea. If we deduct P T from P T Q = 2° 49′ 0″, there will remain Q T = 4′ 34″; and with this distance we shall easily find the height N Q = h', which the coast must have to appear at N′ at the horizon. In fact, if in the preceding formula we substitute Q T for the arc P. T, and h' for the height h, we shall have

$$\text{tang. } Q\,T = \frac{1}{(1-c)} \sqrt{\frac{2h'}{R}};$$

whence we deduce

$$h' = \frac{R\,(1-c)^2 \text{ tang.}^2\, Q\,T}{2} = 202{\cdot}2 \text{ toises.}$$

Thus by means of the refraction, and notwithstanding the curve of the Earth, which at the distance P Q would conceal a mountain of 370 toises, we might sometimes see a mountain situate on the coast only 202 toises high; but as the refractions are uncertain, and may even be negative, it would be imprudent to affirm any thing for such great distances, for which we have no observation.

Results of the determinations of height.

	toises.
Town of Laguna . . .	360
——— Orotava . . .	163
Pino del Dornajito . .	533
Estancia de los Ingleses . .	1552

Cavern of ice . . .	1732
Foot of the Piton . .	1825
Summit of the Peak of Teneriffe .	1909

I have given in the third chapter * the result of the observations of longitude which I made at Santa Cruz. The following are the data taken from M. de Borda's manuscript, and which will serve to complete what has been laid down in the Collection of my astronomical observations (t. i, p. xxxvii and 28). Don Joseph Varela observed, the 30th of August, at the port of Gomera, the emersion of Jupiter's third satellite, at $15^h\ 40'\ 8''$. Tofino saw, at Cadiz, this same emersion, at $16^h\ 23'\ 28''$. Difference of the meridians $43'\ 20''$; the port of la Gomera, being situate, according to the operations of Borda, $0^h\ 3'\ 28''$ to the east of Santa Cruz, we find for this latter place $0^h\ 39'\ 52''$. The 12th of October, Varela observed the immersion of the third satellite at Santa Cruz at $12^h\ 42'\ 11''$. Tofino made the same observation at Cadiz at $13^h\ 22'\ 26''$. Difference of the meridians $0^h\ 40'\ 15''$. The same day the emersion of the third satellite was observed at Santa Cruz at $15^h\ 52'\ 51''$; at Cadiz at $16^h\ 32'\ 54''$. Difference, $0^h\ 40'\ 3''$. The mean of these three observations of satellites, which had not yet been

* Vol. i, p. 115.

published, makes Santa Cruz 18° 36′ 45″ west of Paris, in reckoning with M. de Borda for Cadiz 8° 36′ 0″, conformably to the observation of the annular eclipse of the Sun in 1764, calculated by Du Séjour. But the real longitude of the old observatory of Cadiz being, according to a great number of occultations of stars * calculated by Messrs. Triesnecker and Oltmanns, 8° 37′ 37″; we have thence by the satellites 18° 38′ 22″ for the longitude of Santa Cruz. Varela and Tofino made use of two telescopes two feet and a half long, by Dollond, with which these two observers had often obtained at Cadiz exactly the same results. Two observations of the first and second satellites, made by P. Feuillée, in 1724, at Laguna and Orotava, and compared with the observations of Maraldi at Paris, give 18° 36′ 36″ and 18° 29′ 11″ for Santa Cruz in Teneriffe; supposing, with Borda, Laguna to be 2′ 50″, and Orotava 16′ 5″ west of the Mole of Santa Cruz (Mém. de l'Acad., 1746, p. 123). These data, combined with the chronometrical results, concur in proving what I have enlarged on elsewhere, that the longitude of the Mole is probably not less than 18° 33′, or greater than 18° 36′ or 18° 38′. M. de Borda speaking in his journal of Capt. Cook, whom he had the plea-

* Rec. d'Obs. Astron., t. i, p. 25. Espinosa, Memorias de los Navigantes, t. i, p. 45.

sure to meet at the Canaries, adds, "I cannot conceive why this celebrated navigator, who was acquainted with the determinations of the travellers who preceded him, persists in stating, that the port of Santa Cruz is in 18° 51′ 0′" (Third Voyage, vol. i, p. 19). Before the expedition of the Boussole and the Espiégle, the latitude of the Peak of Teneriffe was generally thought to be 28° 12′ 54″ (Maskelyne, Brit. Mariner's Guide, p. 17). Cook found the Peak, by observations made under sail, 12′ 11″ more to the South, and 29′ 30″ more to the west, than the Mole of Santa Cruz. The geometrical operations of Borda give with more exactness 11′ 37″ difference in latitude, and 23′ 4″ difference in longitude. At the Mole, the Peak has been determined by azimuths West 28° 55′ South; the angle of apparent height being 4° 37′. Distance 22740 toises, supposing the elevation of the volcano to be 1904 toises. Latitude of the Peak 28° 16′ 53″. Longitude 18° 59′ 54′. I give here all that relates to this celebrated mountain, in order to induce navigators to verify results, which are so important to nautical geography.

M. de Borda is the only traveller, who has compared in an accurate manner the dip of the needle at Santa Cruz, and at the top of the Peak of Teneriffe. He found the latter 1° 15′ greater

(Manuscrit du Dépôt, Cah. 4). This increase of the dip observed on the summit of a high mountain is conformable to what I have several times remarked in the chain of the Andes. It probably depends on some system of local attractions; but in order to form a right judgment of this phænomenon, we should know with precision the dip of the magnetic needle at the foot of the volcano, for instance at the town of Orotava. The variation in 1776 was 15° 45′ at Gomera, 15° 50′ at the Mole of Santa Cruz, and 19° 40′ toward the north west, at the brink of the crater.

BOOK II.

CHAPTER IV.

First abode at Cumana.—Banks of the Manzanares.

We anchored opposite the mouth of the river Manzanares on the 16th of July, at break of day; but we could not land till very late in the morning, because we were obliged to wait the visit of the officers of the port. Our eyes were fixed on the groups of cocoa-trees that border the river, and the trunks of which, more than sixty feet high, towered over the landscape. The plain was covered with tufts of cassias, capers, and those arborescent mimosas, which, like the pine of Italy, extend their branches in the form of an umbrella. The pinnated leaves of the palms were conspicuous on the azure of a sky, the clearness of which was unsullied by any trace of vapors. The Sun was ascending rapidly toward the zenith. A dazzling light was spread through the air, along the whitish hills strewed with cylindric cactuses, and over a sea ever calm, the shores of which were

peopled with alcatras*, egrets, and flamingoes. The splendor of the day, the vivid coloring of the vegetable world, the forms of the plants, the varied plumage of the birds, every thing announced the grand aspect of nature in the equinoctial regions.

The city of Cumana, the capital of New Andalusia, is a mile distant from the *embarcadere*, or the battery of the *Bocca*, where we landed, after having passed the bar of the Manzanares. We had to cross a vast plain†, which divides the suburb of the Guayquerias from the seacoast. The excessive heat of the atmosphere was augmented by the reverberation of the soil, partly stripped of vegetation. The centigrade thermometer, plunged into the white sand, rose to 37·7°. In the small pools of salt water it kept at 30·5°, while the heat of the ocean, at its surface, is generally in the port of Cumana‡ from 25·2° to 26·3°. The first plant

* Brown pelican of the size of a swan. Buffon, pl. eulum No. 957. Pelicanus fuscus, Lin. (Oviedo, lib. xiv, c. 6.)

† El Salado.

‡ On comparing a great number of experiments made in 1799 and 1800, at different seasons, I find, that in the port of Cumana, to the north of Cerro Colorado, the sea during the ebb is 0·8° warmer than during the flow, whatever be the hour of the tide. I shall here give the observations of the 20th of October, which may almost serve as a type, and which were made on a point of the coast, where the sea at 150 toises distance was 30 or 40 fathoms deep. At ten in the morning, ebb 26·1°; air near the coast 27·4°; air near the city 30·2°; water of the Manzanares 25·2°: at four in

that we gathered on the continent of America was the avicennia tomentosa*, which in this place scarcely reaches two feet high. This shrub, the sesuvium, the yellow gomphrena, and the cactus, cover the lands impregnated with muriat of soda; they belong to that small number of plants, which live in society like the heath of Europe, and which in the torrid zone are found only on the seashore, and on the elevated plains of the Andes†. The avicennia of Cumana is distinguished by another peculiarity not less remarkable: it furnishes an instance of a plant common to the shores of South America and the coasts of Malabar.

The Indian pilot led us across his garden, which rather resembled a copse than a piece of cultivated ground. He showed us, as a proof of the fertility of this climate, a silk-cotton tree *(bombax heptaphyllum)*, the trunk of which, in its fourth year, had reached nearly two feet and a half in diameter. We have observed, on the banks of the Orinoco and the river Magdalena, that the bombax,

the afternoon, flow 25·3°; air near the coasts 26·2°; air at Cumana 28·1°; water of the Manzanares 25·7°.

* Mangle prieto.

† On the extreme rarity of the *social plants* between the tropics, see my Essay on the Geog. of Plants, p. 19; and a paper by Mr. Brown on the *Proteaceæ* (Trans. of the Lin. Soc. vol. x, P. 1, p. 23), in which this great botanist has extended and confirmed by numerous facts my ideas on the associations of plants of the same species.

the carolinea, the ochroma, and other trees of the family of the malvaceæ, are of extremely rapid growth. I nevertheless think, that there was some exaggeration in the report of the Indian respecting the age of his bombax; for under the temperate zone, in the hot and damp lands of North America, between the Missisippi and the Alleghany mountains, the trees do not exceed a foot in diameter* in ten years; and vegetation is in general but a fifth more speedy than in Europe, even taking as an example the platanus occidentalis, the tulip tree, and the cupressus disticha, which reach from nine to fifteen feet in diameter. On the strand of Cumana, in the garden of the Guayqueria pilot, we saw for the first time a *guama*† loaded with flowers, and remarkable for the extreme length and silvery splendor of it's numerous stamina. We crossed the suburb of the Indians, the streets of which are very regular,

* Five feet above the ground. These measures were taken by an excellent observer, Mr. Michaux.

† *Inga spuria*, which we must not confound with the common inga, inga vera, Willd. (mimosa inga, Lin.). The white stamina, to the number of sixty or seventy, are attached to a greenish corolla, have a silky lustre, and are terminated by a yellow anther. The flower of the *guama* is eighteen lines long. The common height of this fine tree, which prefers a moist soil, is from eight to ten toises. I shall observe on this occasion, that we have distinguished in this work by italics the names of the new plants, which M. Bonpland and myself have collected.

and formed of small houses, quite new, and of a pleasing appearance. This part of the town had just been rebuilt, on account of the earthquakes, which had laid Cumana in ruins eighteen months before our arrival. Scarcely had we passed, on a wooden bridge, the Manzanares, which contains a few *bavas*, or crocodiles of the smaller species, when we every where perceived the traces of this horrible catastrophe; new edifices were rising on the ruins of the old.

We were conducted by the captain of the Pizarro to the governor of the province, Don Vincente Emparan, to present to him the passports which had been given us by the first secretary of state. He received us with that frankness, and that noble simplicity, which has at all times characterized the Biscayan nation. Before he was named governor of Portobello and Cumana, he had distinguished himself as captain of a vessel in the royal navy. His name recalls to mind one of the most extraordinary and distressing events recorded in the history of maritime wars. At the time of the last rupture between Spain and England, two brothers of M. d'Emperan fought during a whole night before the port of Cadiz, taking each other's ship for an enemy's. The battle was so terrible, that both vessels were sunk nearly at the same time. A very small part of the crew was saved, and the two brothers had the misfortune

to recognize each other a little before they expired.

The governor of Cumana expressed his great satisfaction at the resolution we had taken to remain for some time in New Andalusia, the name of which province at this period was very little known in Europe, and which in its mountains, and on the banks of its numerous rivers, contains a great number of objects worthy of fixing the attention of naturalists. Mr. de Emparan showed us cottons dyed with native plants, and fine furniture which was made exclusively with the wood of the country: he interested himself much in every thing that related to natural philosophy; and asked, to our great astonishment, if we thought, that, under the beautiful sky of the tropics, the atmosphere contained less azot (azotico) than in Spain; or if the rapidity, with which iron oxidates in those climates, was only the effect of a greater humidity indicated by the hair hygrometer. The name of his native country pronounced on a distant shore would not have been more agreeable to the ear of a traveller, than those words of azot, oxyd of iron, and hygrometer, were to ours. We knew, that, notwithstanding the orders of the court, and the recommendations of a powerful minister, our abode in the Spanish climates would expose us to numberless inconveniences, if we did not succeed in inspiring some personal

interest in those who govern those vast countries. Mr. de Emparan loved the sciences too well, to deem it strange that we should come from so great a distance to collect plants, and determine the position of a few places by astronomical methods. He suspected no other motives for our voyage than those mentioned in our passports; and the public marks of consideration, which he gave us during a long abode in his government, contributed greatly to procure us a favourable welcome in every part of South America.

We disembarked our instruments toward the evening, and we had the pleasure to find, that none had been damaged. We hired a spacious house, the situation of which was favourable for astronomical observations. We enjoyed an agreeable coolness, when the breeze arose; the windows were without glasses, and even wanted those paper panes, which are often the substitutes of glass at Cumana. The whole of the passengers aboard the Pizarro left the vessel, but the recovery of those who had been attacked by the fever was very slow. We saw some, who a month after, notwithstanding the care bestowed on them by their countrymen, were still extremely weak and reduced. Hospitality, in the Spanish colonies, is such, that a European who arrives, without recommendation, or pecuniary means, is almost sure of finding assistance, if he lands in any port on account of sickness. The Catalans, the Gallicians,

and the Biscayans, have the most frequent intercourse with America. They there form as it were three distinct corporations, which exercise a remarkable influence over the morals, the industry, and commerce of the colonies. The poorest inhabitant of Siges or Vigo is sure of being received into the house of a Catalan or Gallician pulpero *, whether he arrives at Chili, or at the Philippine Islands. I have seen the most affecting instances of these attentions rendered to unknown persons, during whole years, and always without a murmur. It has been said, that hospitality was easy to be exercised in a happy climate, where food is in plenty, where the native plants yield salutary remedies, and where the sick man, reposing in his hammock, finds under a shed all the shelter of which he stands in need. But should we consider as of little value the embarrassment caused in a family by the arrival of a stranger, whose character is unknown? can we be permitted to forget those marks of tender compassion, those endearing attentions of the female part of the household, that untired patience, which never relaxes during a long and painful recovery? It has been remarked, that, with the exception of a few very populous towns, hospitality has not yet perceptibly diminished since the first establishment of the Spanish colonists in the new world. It is distressing to think, that this

* A retail dealer.

change will take place, when population and colonial industry shall have made more rapid progress; and that this state of society, which we are agreed to call an advanced state of civilization, will by degrees have banished "the Old Castilian frankness."

Among the sick who landed at Cumana was a negro, who fell into a state of insanity a few days after our arrival; he died in this deplorable condition, though his master, almost seventy years old, who had left Europe to settle at Sans Blas, at the entrance of the gulf of California, had attended him with the greatest care. I relate this fact as a proof of its sometimes happening, that men born under the torrid zone, after having dwelt in temperate climates, feel the pernicious effects of the heat of the tropics. The negro was a young man, eighteen years of age, very robust, and born on the coast of Guinea: an abode of some years on the high plain of Castile, had given his organization that kind of irritability, which renders the miasms of the torrid zone so dangerous to the inhabitants of the countries of the north.

The soil, on which Cumana is built, forms part of an extent of ground, that is very remarkable in a geological point of view. As since my return to Europe, other travellers have preceded me in the description of certain parts of the coasts, which they have visited after me, I shall here confine myself to observations on subjects, that have

formed no part of their studies. The chain of the calcareous Alps of Bergantin and Tataraqual stretches east and west from the summit of Imposible to the port of Mochima and to Campanario. The sea, in times far remote, appears to have divided this chain of the rocky coasts of Araya and Maniquarez. The vast gulf of Cariaco is owing to an irruption of the sea; and no doubt can be entertained, but that at this period the waters covered, on the southern bank, the whole of the ground impregnated with muriat of soda, through which flows the Manzanares. It requires but a slight inspection of the topographical plan of the city of Cumana, to render this fact as incontestable as the ancient abode of the sea on the basins of Paris, Oxford, and Rome. The slow retreat of the waters has turned into dry ground this extensive plain, in which rises a group of small hills, composed of gypsum and calcareous breccia of very recent formation.

The city of Cumana is backed by this group, which was formerly an island of the gulf of Cariaco. That part of the plain, which is north of the city, is called *Plaga Chica*, and extends eastwards as far as *Punta Delgada*; where a narrow valley, covered with yellow gomphrena, still marks the point of the ancient outlet of the waters. This valley, the entrance of which is defended by no exterior works, is the point, where the place is most exposed to a military attack. An enemy

might pass in perfect safety between the sandy point of Barigon* and the mouth of the Manzanares; where the sea, near the entrance of the gulf of Cariaco, is forty or fifty fathoms deep, and farther to the south-east, even as much as eighty-seven fathoms. A landing might be effected near Punta Delgada; and Fort St. Antonio and the city of Cumana turned, without any apprehension from the western batteries formed at Plaga Chica †, at the mouth of the river, and at Cerro Colorado.

The hill of calcareous breccia, which we have just regarded as an island in the ancient gulf, is covered with a thick forest of columnar cactus and opuntia. Some, thirty or forty feet high, covered with lichens, and divided into several branches in the form of candelabras, wear a singular appearance. Near Maniquarez, at Punta Araya, we measured a cactus, the trunk of which was four feet nine inches in circumference ‡. A European acquainted only with the opuntia in our hot-houses is surprised to see the wood of this plant become so hard from age, that it resists for centuries both air and moisture, and that the Indians of Cumana

* Punta Arenas del Barigon, to the south of the castle of Araya.

† To the west of Los Serritos.

‡ Tuna macho. We distinguish in the wood of the cactus the medullary prolongations, as M. Desfontaines has already observed (Journ. de Physique, t. xlviii, p. 153).

employ it in preference for oars and door posts. Cumana, Coro, the island of Margaretta, and Curassoa, are the places of South America that abound most in plants of the family of the nopals. There only a botanist after a long residence could compose a monography of the genus cactus; the species of which vary not only in their flowers and fruits, but in the form of their articulated stem, the number of costæ, and the disposition of the thorns. We shall see hereafter how these plants, which characterize a warm and extraordinarily dry climate, like that of Egypt and California, gradually disappear in proportion as we remove from the coasts, and penetrate into the inland country.

The groups of cactus and opuntia produce the same effect in the arid lands of equinoxial America, as the junceæ and the hydrocharides in the marshes of our northern climes. A place where the larger species of the strong cactus are collected in groups is considered as almost impenetrable. These places, called *tunales*, are impervious not only to the native, who goes naked to the waist, they are formidable even to those who go fully clothed. In our solitary rambles, we sometimes endeavoured to penetrate into the tunal that crowns the summit of the castle hill, a part of which is crossed by a pathway, where we might study, amidst thousands, the organization of this singu-

lar plant. Sometimes the night suddenly overtook us, for there is scarcely any twilight in this climate; and we then found ourselves in a situation so much the more disagreeable, as the *cascabel*, or rattlesnake*, the *coral*, and other vipers, armed with poisonous fangs, frequent, at the time of laying, these scorched and arid haunts, to deposite their eggs in the sand.

The castle of St. Antonio is built at the eastern extremity of the hill, but not on the most elevated point, being commanded on the east by an unfortified summit. The tunal is considered both here and every where in the Spanish colonies as a very important means of military defence; and when earthen works are raised, the engineers are eager to propagate the thorny opuntia, and promote its growth, as they are careful to keep crocodiles in the ditches of fortified places. Under a climate where organized nature is so powerful and active, man summons as auxiliaries in his defence the carnivorous reptile, and the plant with its armor of formidable thorns.

The casle of St. Antonio, on which the Spanish flag is hoisted on festivals, is only thirty toises above the level of the waters in the gulf of Cariaco †. Placed on a naked and calcareous hill,

* Crotalus cumanensis, &c. Lœflingii, two new species. See my Recueil d'Observ. Zoologiques, t. ii, p. 8.

† This elevation is concluded from the zenith distance of the staff on which signals are hoisted. I found in the great square

it commands the town, and forms a very picturesque object to vessels entering the port. It forms a bright object against the dark curtains of those mountains, which raise their summits to the region of the clouds, and of which the vaporous and bluish tint blends itself with the azure of the sky. On descending from Fort St. Antonio toward the southwest, we find on the slope of the same rock the ruins of the old castle of St. Mary. This site is delightful to those, who wish to enjoy, toward sunset, the freshness of the breeze, and the view of the gulf. The lofty summits of the island of Margaretta* present themselves above the rocky coast of the isthmus of Araya; toward the west, the small islands of Caracas, Picuita, and Boracha, recall to mind the catastrophes, that have overwhelmed the coasts of Terra Firma. These islets bear the resemblance of fortifications, and from the effect of the mirage, while the inferior strata of the air, the ocean, and the soil, are unequally heated by the Sun, their points appear raised like the extremity of the great promontories of the coast. It is pleasing, during the day, to follow these

of Cumana this angle, not corrected for refraction, 83° 2′ 10″. According to the topographical plan of Cumana, laid down in 1793 by Mr. Fidalgo, the horizontal distance of the Gran Plaza from the Castillo de San Antonio is 220 toises.

* The promontory of Macanao.

inconstant phænomena*: we see, as the night approaches, these stony masses, that had been suspended in the air, settle themselves on their bases; and the luminary, the presence of which vivifies organic nature, seems by the variable inflection of its rays to impress motion on the stable rock, and give an undulating movement to plains covered with arid sands.

The city of Cumana, properly speaking, occupies the ground that lies between the castle of St. Antonio, and the small rivers of Manzanares and Santa Catalina. The Delta, formed by the bifurcation of the first of these rivers, is a fertile plain covered with mammees, sapotas *(achras)*, plantains, and other plants cultivated in the gardens or *sharas* of the Indians. The town has no remarkable edifice, and the frequency of earthquakes forbids such embellishments. It is true, that strong shocks occur less frequently in a given time at Cumana, than at Quito, where we nevertheless find sumptuous and very lofty churches. But the earthquakes of Quito are violent only in appearance; and, from the particular nature of the motion and of the ground, no edifice there is overthrown. At Cumana, as well as at Lima,

* The real cause of the mirage, or the extraordinary refraction which the rays undergo, when strata of air of different densities are placed on each other, had already been suspected by Hooke. See his Posthumous works, p. 472.

and in several cities placed far from the mouths of burning volcanoes, it happens, that the series of slight shocks is interrupted after a long course of years by great catastrophes, that resemble the effects of the explosion of a mine. We shall have occasion to return several times to this phænomenon, for the explanation of which so many vain theories have been imagined, and which have been thought to be classed, by attributing them to perpendicular and horizontal movements, to the shock, and to oscillation *.

The suburbs of Cumana are almost as populous as the ancient town. We reckon three, that of the Serritos, on the road to the Plaga Chica, where we meet with some fine tamarind trees; that of St. Francis, toward the south east; and the great suburb of the Guayquerias, or Guayguerias. The name of this tribe of Indians was quite unknown before the conquest. The natives who bear this name formerly belonged to the nation of the Guaraounoes, of which we find no remains but in the swampy lands of the branches of the Orinoco. Old men have assured me, that the language of their ancestors was a dialect of the Guaraouno; but that for a century past no

* This classification dates from the time of Posidonius. It is the *succussio* and *inclinatio* of Seneca (Nat. Quæst. 6, c. 21): but the ancients had already judiciously remarked, that the nature of these shocks is too variable, to permit any subjection to those imaginary laws. (Plato, apud Plut., de Placit. Philos., lib. iii, c. 15, ed. Reiske, t. ix, p. 551.)

native of that tribe at Cumana, or in the island of Margaretta, has spoken any other language than the Castilian.

The denomination of Guayquerias, like those of Peru and Peruvian, owes its origin to a mere mistake. The companions of Christopher Columbus, coasting along the island of Margaretta, where still on the northern coast resides the noblest portion of the Guayqueria nation *, met a few natives, who were harpooning fish by throwing a pole tied to a cord, and terminated by an extremely sharp point. They asked them in the Hayti language their name; and the Indians, thinking that the question of the strangers related to their harpoons, formed of the hard and heavy wood of the *macana* palm tree, answered *guaike, guaike*, which signifies *pointed pole.* A striking difference at present exists between the Guayquerias, a civilized tribe of skilful fishermen, and

* The Guayquerias of la Banda del Norte consider themselves as the most noble race, because they think, that they are less mixed with the Chayma Indian, and other copper-coloured races. They are distinguished from the Guayquerias of the continent by their manner of pronouncing the Spanish, which they speak almost without separating their teeth. They show with pride to Europeans the point of the Galera, so called on account of the vessel of Columbus, which anchored there, and the port of Manzanillo, where they first swore to the Whites, in 1498, that friendship, which they have never betrayed, and which has given them, in the Court style, the title of *fieles*, loyal. (See above, p. 43).

those savage Guaraounoes of the Orinoco, who suspend their habitations on the trunks of the mauritia palm tree, *moriche*.

The population of Cumana has been singularly exaggerated in latter times. In 1800, several colonists, little versed in questions of political economy, carried this population to twenty thousand souls; while the king's officers employed in the government of the country thought, that the city with its suburbs did not contain twelve thousand. Mr. Depons, in his valuable work on the province of Caracas, gives Cumana, in 1802, near twenty eight thousand inhabitants,; others have carried this number, for the year 1810, to thirty thousand. When we consider the slowness, with which the population increases in Terra Firma, I do not speak of the country, but in the towns, we must doubt whether Cumana be already a third more populous than Vera Cruz, the principal port of the vast kingdom of New Spain. It is even easy to prove, that in 1802 the population scarcely exceeded eighteen or nineteen thousand souls. I was favoured with a sight of the different memoirs, which the government had procured to be drawn up on the statistics of the country, at the time when the question was agitated, whether the revenue of the farm of tobacco could be replaced by a personal tax; and I flatter myself, that my estimation rests on solid foundations.

An enumeration made in 1792 gives Cumana but 10740 inhabitants, reckoning the suburbs and scattered houses a league around. Don Manuel Navarete, an officer of the treasury, asserts, that the error of this enumeration cannot be a third, or even a fourth of the whole number. On comparing the annual registers of baptisms, we observe but a feeble increase from 1790 to 1800. The women, it is true, are extremely fruitful, especially the natives; but though the small-pox be yet unknown in this country, the mortality of infants is prodigious, on account of the extreme carelessness in which they live, and the pernicious custom of eating green and indigestible fruits. The number of births * generally amounts from five hundred and twenty to six hundred, which indicates at most a population of sixteen thousand eight hundred souls. We may be assured, that all the Indian children are baptised, and in-

* The following are the results which I drew from the registers communicated to me by the parish priests of Cumana. Births in the year 1798, in the district of the *Curas rectores*, 237; in the district of the *Curas castrenses*, 57; in the suburb of the Guayquerias, or parish of Alta Gracia, 209; in the suburb of the Serritoes, or parish of Socorro, 19. Total 522. We see, by these parish registers, the great fecundity of the Indian marriages; for though the suburb of the Guayquerias contains a number of individuals of other tribes, we are struck with the quantity of children born on this left bank of the Manzanares. Their number amounts to two fifths of the whole births.

scribed on the registers of the parishes; and supposing, that the population in 1800 had been twenty six thousand souls, there would have been but one single birth to forty-three individuals; while the ratio of births to the whole population is in France as twenty-eight to a hundred, and in the equinoctial regions of Mexico as seventeen to a hundred.

It is to be presumed, that the Indian suburb by degrees will extend as far as the *Embarcadere*, the plain, which is not yet covered with houses or huts, being more than 340 toises in length *. The heats are somewhat less oppressive on the side toward the seashore, than in the old town, where the reverberation of the calcareous soil, and the proximity of the mountain of St. Antonio, raise the temperature to an extraordinary degree. In the suburb of the Guayquerias, the sea breezes have free access; the soil is clayey, and, as it is thought, less exposed from this reason to the violent shocks of earthquakes, than the houses at the

* I have deduced this distance from the vertical angles and the azimuths of several edifices, of which I carefully measured the height. On the side of the river, in 1800, the distance from the first hut of the suburbs of the Guayquerias to the Casa blanca (of Don Pasqual Goda) was 538 toises, and from this first hut to the bridge of the Manzanares 210 toises. These data will some day be interesting, when the progress of industry and prosperity at Cumana, from the beginning of the nineteenth century, becomes a subject of inquiry.

foot of the rocks and hills on the right bank of the Manzanares.

The shore near the mouth of the small river Santa Catalina is bordered with mangrove trees*, but these mangroves are not sufficiently spread to diminish the salubrity of the air of Cumana. The soil of the plain is in part destitute of vegetation, in part covered with tufts of sesuvium portulacastrum, gomphrena flava, *g. myrtifolia*, talinum cuspidatum, *t. cumanense*, and portulaca lanuginosa. Among these herbaceous plants we find at intervals the avicennia *tomentosa*, the scoparia dulcis, a frutescent mimosa with very irritable leaves†, and particularly cassias, the number of which is so great in South America, that we collected, in our travels, more than thirty new species.

On leaving the Indian suburb, and ascending the river toward the south, we found a grove of cactus, a delightful spot, shaded by tamarinds, brasillettoes, bombax, and other plants, remarkable

* Rhizophora mangle. M. Bonpland found on the Plaga Chica the allionia incarnata, in the same place where the unfortunate Lœfling had discovered this new genus of nyctagines.

† The Spaniards designate by the name of *dormideras* (sleeping plants) the small number of mimosas with irritable leaves. We have increased this number with three species, which were unknown to botanists, namely, the mimosa *humilis* of Cumana, the m. *pellita* of the savannahs of Calabozo, and the m. *dormiens* of the banks of the Apura.

for their leaves and flowers. The soil here is rich in pasturage, where dairy houses, built with reeds, are separated from each other by clumps of trees. The milk remains fresh, when kept, not in the calebashes* of very thick ligneous fibres, but in porous earthen vessels from Maniquarez. A prejudice prevalent in the countries of the north had long led me to believe, that cows, under the torrid zone, did not yield rich milk; but my abode at Cumana, and especially an excursion through the vast plains of Calabozo, covered with grasses, and herbaceous sensitive plants, convinced me, that the ruminating animals of Europe become perfectly habituated to the most scorching climates, provided they find water and good nourishment. The milk is excellent in the provinces of New Andalusia, Barcelona, and Venezuela; and the butter is better in the plains of the equinoctial zone, than on the ridge of the Andes, where the Alpine plants, enjoying in no season a sufficiently high temperature, are less aromatic than on the Pyrenees, the mountains of Estremadura, and those of Greece. As the inhabitants of Cumana prefer the coolness of the sea breeze to the appearance of vegetation, they are accustomed to no other walk than that of the open shore. The Spaniards, who are accused in general of no predilection for trees, or the warbling of birds, have transported

* The fruit of the crescentia cujete.

their prejudices and their habits into the colonies. In Terra Firma, Mexico, and Peru, it is rare to see a native plant a tree, merely with the view of procuring himself shade; and if we except the environs of the great capitals, walks bordered with trees are almost unknown in these countries. The arid plain of Cumana exhibits after violent showers an extraordinary phænomenon. The earth, drenched with rain, and heated again by the rays of the sun, emits that musky odour, which under the torrid zone is common to animals of very different classes, to the jaguar, the small species of tiger cat, the thick-nosed tapir*, the galinazo vulture†, the crocodile, vipers, and rattlesnakes. The gaseous emanations, which are the vehicles of this aroma (odour), seem to be evolved in proportion only as the mould, containing the spoils of an innumerable quantity of reptiles, worms, and insects, begins to be impregnated with water. I have seen Indian children, of the tribe of the Chaymas, draw out from the earth and eat millepedes or scolopendras‡ eighteen inches long, and seven lines broad. Whenever the soil is turned

* Cavia capybara, Lin.; chiguire.

† Vultur aura, Lin., zamuro, or galinazo. The Brasilian vulture of Buffon. I cannot reconcile myself to the adoption of names, which designate as belonging to a single country animals common to a whole continent.

‡ Scolopendras are very common behind the castle of St. Antonio, on the summit of the hill.

up, we are struck with the mass of organic substances, which by turns are developed, transformed, and decomposed. Nature in these climates appears more active, more fruitful, we might even say more prodigal of life.

On this shore, and near the dairies of which we have just spoken, we enjoy, especially at sunrise, a very beautiful prospect over an elevated group* of calcareous mountains. As this group subtends an angle of three degrees only at the house where we dwelt, it long served me to compare the variations of the terrestrial refraction

* If the Brigantine *(Cerro del Bergantin)* be actually 24 miles, or 22800 toises distant from Cumana, as is indicated on the chart of Mr. Fidalgo, published by the Hydrographical Depôt at Madrid, in 1805, the angles of altitude which I took at the *Plaga grande* make this mountain 1255 toises high. But this very chart, less accurate with regard to places distant from the coasts than to the coasts themselves, assigns the town of Cumanacoa a latitude of 10° 5′, while, according to my direct observations, it is 10° 16′ 11″. (Obs. Astron. t. i, p. 96.) If this too southern position has an influence on that of the Brigantine, we must admit, that this mountain is much lower. It presents itself at the Plaga Grande under a vertical angle (corrected for the refraction and curve of the Earth) of 3° 6′ 12″. Other angles, taken on a base of 196 toises, which was measured on ground where the water had rested a long time, would induce me to think, that the height and distance of the Brigantine are not much above 800 toises, and 12 or 16 miles; but we can have no confidence in so short a basis, and an operation, the immediate object of which was not the measure of the Brigantine.

with the meteorological phænomena. Storms are formed in the centre of this Cordillera; and we see from afar thick clouds resolve themselves into abundant rains, while during seven or eight months not a drop of water falls at Cumana. The Brigantine, which is the highest part of this chain, raises itself in a very picturesque manner behind Brito and Tataraqual. It took its name from the form of a very deep valley on the northern declivity, which resembles the inside of a ship. The summit of this mountain is almost bare of vegetation, and flattened like that of Mowna-Roa, in the Sandwich Islands. It is a perpendicular wall, or, to use a more expressive term of the Spanish navigators, a table, *mesa.* This peculiar physiognomy, and the symmetrical arrangement of a few cones, which surround the Brigantine, made me at first think, that this group, which is wholly calcareous, contained rocks of basaltic or trappean formation.

The governor of Cumana had sent, in 1797, a band of determined men to explore this entirely desert country, and to open a direct road to New Barcelona, by the summit of the *Mesa.* It was reasonably expected, that this way would be shorter, and less dangerous to the health of travellers, than that which was pursued by the couriers along the coasts; but every attempt to cross the chain of the mountains of the Brigantine was fruitless.

In this part of America, as in New Holland* to the west of Sidney Town, it is not so much the height of the Cordilleras, as the form of the rocks, that presents obstacles difficult to surmount.

The longitudinal valley, formed by the lofty mountains of the interior and the southern declivity of the Cerro de San Antonio, is traversed by the Rio Manzanares. This plain, which is the only thoroughly wooded part in the environs of Cumana, is called the Plain des Charas†, on account of the numerous plantations, which the inhabitants have begun for some years past along the river. A narrow path leads from the hill of San Francisco across the forest to the *hospice* of the Capuchins, a very agreeable country house, which the Arragonese monks have built as a retreat for old infirm missionaries, who can no longer fulfil the duties of their ministry. As we advance toward the west, the trees of the forest become more vigorous, and we meet with a few monkeys‡, which, however, are very rare in the environs of Cumana. At the foot of the capparis, the bauhinia, and the

* The blue mountains of New Holland, and those of Carmarthen and Lansdown, are not visible, in clear weather, beyond fifty miles. Peron, Voyage aux Terres Australes, p. 389. Supposing the angle of altitude half a degree, the absolute height of these mountains would be about 620 toises.

† *Chacra*, by corruption *chara*, a hut or cottage surrounded by a garden. The word *ipure* has the same signification.

‡ The common *machi*, or weeping monkey.

zygophyllum with flowers of a gold yellow, extends a carpet of bromelia*, akin to the b. karatas, which from the odour and coolness of its foliage attracts the rattlesnake.

The waters of the Manzanares are very limpid, and happily it has no resemblance whatever to the Manzanares of Madrid, which appears the narrower from the contrast of the sumptuous bridge by which it is crossed. It takes its source, like all the rivers of New Andalusia, in a part of the savannahs (llanos) known by the names of the *plateaux* of Jonoro, Amana, and Guanipa†, which receives, near the Indian village of San Fernando, the waters of the Rio Juanillo. It has been several times proposed to the government, but always without success, to construct a dyke at the first *Ipure*, in order to form artificial irrigations in the plain of Charas; because, notwithstanding its apparent sterility, the soil is extremely productive, wherever humidity is joined to the heat of the climate. The cultivators, who are but in narrow circumstances at Cumana, were gradually to refund the money advanced for the construction of the sluices. Meanwhile Persian wheels, pumps

* Chihuchihue, of the family of the ananas.

† These three eminences bear the names of *Mesas*, tables. An immense plain has an almost imperceptible rise from both sides to the middle, without any appearance of mountains or hills.

worked by mules, and other hydraulic but imperfect machines, have been erected, to serve till this project is carried into execution.

The banks of the Manzanares are very pleasant, and shadowed by mimosas, erythrinas, ceibas, and other trees of gigantic growth. A river, the temperature of which, in the season of the floods, descends as low as twenty-two degrees, when the air is at thirty and thirty-three degrees, is an inestimable benefit, in a country where the heats are excessive during the whole year, and where it is so agreeable to bathe several times in the day. The children pass, as it were, a part of their lives in the water: the whole of the inhabitants, even the women of the most opulent families, know how to swim; and in a country where man is so near the state of nature, one of the first questions asked at first meeting in the morning is, whether the water is cooler than the preceding evening. The mode of bathing is various enough. We every evening visited a very respectable society, in the suburb of the Guayquerias. In a fine moonlight night, chairs were placed in the water; the men and women were lightly clothed, as in some baths of the north of Europe; and the family and strangers, assembled in the river, passed some hours in smoking segars, and in talking, according to the custom of the country, of the extreme dryness of the season, of the abundant rains in the neighbouring districts, and particularly of the lux-

uries, of which the ladies of Cumana accuse those of the Caraccas and the Havannah. The company were under no apprehensions from the bavas, or small crocodiles, which are now extremely scarce, and which approach men without attacking them. These animals are three or four feet long. We never met with them in the Manzanares, but with a great number of dolphins*, which sometimes ascend the river in the night, and frighten the bathers by spouting water.

The port of Cumana is a road capable of receiving all the navies of Europe. The whole of the Gulf of Cariaco, which is thirty-five miles long, and sixty-eight miles broad, affords excellent anchorage. The great ocean is not more calm and pacific on the coasts of Peru, than the sea of the Antilles from Portocabello, and especially from Cape Codera, to the Point of Paria. The hurricanes of the West Indies are never felt in these regions, the vessels of which are without decks. The only danger in the port of Cumana is a shoal, that of Morro Roxo†, which is nine hundred toises

* Toninas.

† There are from one to three fathoms water on this shoal, while just beyond its edges there are eighteen, thirty, and even thirty-eight. The remains of an old battery, situate to the north north east of the castle of St. Antonio, and very near it, serve as a mark to avoid the bank of Morro Roxo. Before this battery shuts in with a very high mountain of the peninsula of Araya, which bears from the castle of St.

broad from east to west, and so steep, that you are upon it almost before you have any warning of it.

I have been somewhat diffuse in my description of the site of Cumana, because it appeared to me important to make known a place, which for ages has been the focus of the most tremendous earthquakes. Before I speak of these extraordinary phænomena, it will be useful to collect the scattered traits of the physical position of which I have just given the sketch.

The city, placed at the foot of a hill destitute of verdure, is commanded by a castle. No steeple or dome attracts from afar the eye of the traveller, but only a few trunks of tamarind, cocoa, and date trees, which rise above the houses, the roofs of which are flat. The surrounding plains, especially those on the coasts, wear a melancholy, dusty, and arid appearance, while a fresh and luxuriant vegetation points out from afar the windings of the river, which separates the city from the suburbs, the population of European and mixed race from the natives with a coppery tint. The hill of fort St. Antonio, solitary, white, and bare, reflects a great mass of light, and of radiant heat:

Antonio, north 65° 30′ east, at six leagues distance, the ship must be put about. If this be neglected, the danger of striking is so much the greater, as the heights of Bordones keep the wind from a vessel steering for the port.

it is composed of breccia, the strata of which contain pelagian petrifactions. In the distance, toward the south, a vast and gloomy curtain of mountains stretches along. These are the high calcareous Alps of New Andalusia, surmounted by sandstone, and other more recent formations. Majestic forests cover this Cordillera of the interior, and are joined by a woody vale to the open, clayey lands, and salt marshes of the environs of Cumana. A few birds of considerable size contribute to give a particular physiognomy to these countries. On the seashore, and in the gulf, we find flocks of fishing herons, and alcatras of a very unwieldy form, which swim, like the swan, raising their wings. Nearer the habitation of men, thousands of galinazo vultures, the true jackals of the winged tribe, are ever busy in uncovering the carcases of animals*. A gulf, which contains hot and submarine springs divides the secondary from the primary and schistose rocks of the peninsula of Araya. Each of these coasts is bathed by a tranquil sea, of an azure tint, and always gently agitated by the same wind. A bright and clear sky, with a few light clouds at sunset, reposes on the ocean, on the peninsula destitute of trees, and on the plains of Cumana, while we see the storms accumulate and descend in fertile showers among the inland mountains. Thus on these coasts, as well as at the

* Buffon, Hist. Nat. des Oiseaux, t. i, p. 114.

foot of the Andes, the earth and the skies offer the extremes of clear weather and fogs, of drought and torrents of rain, of absolute nudity and never ceasing verdure. In the New Continent, the low regions on the seacoasts differ as widely from the inland mountainous districts, as the plains of Lower Egypt from the high lands of Abyssinia.

The analogies which we have just indicated, between the seacoasts of Andalusia and those of Peru, extend themselves also to the frequency of earthquakes, and the limits which nature seems to have prescribed to these phænomena. We have ourselves felt very violent shocks at Cumana; and, at the moment while the edifices recently overthrown were rebuilding, we were informed on the spot of the most minute circumstances, that accompanied the great catastrophe of the 14th of December, 1797. These observations will be perhaps the more interesting, as earthquakes have hitherto been considered rather in the fatal effects which they have had on the population and welfare of society, than under a physical and geological point of view.

It is a very generally received opinion on the coasts of Cumana, and in the island of Margaretta, that the gulf of Cariaco owes its existence to a rent of the continent attended by an irruption of the ocean. The remembrance of this great revolution was preserved among the Indians to the end of the fifteenth century; and it is related, that, at

the time of the third voyage of Christopher Columbus, the natives mentioned it as a very recent event. In 1530, the inhabitants were alarmed by new shocks on the coasts of Paria and Cumana. The lands were inundated by the sea, and the small fort, built by James Castellon at New Toledo *, was entirely destroyed. At the same time an enormous opening was formed in the mountains of Cariaco, on the shores of the gulf that bears this name, when a great body of salt water, mixed with asphaltum, issued from the micaceous schist †. Earthquakes were very frequent toward the end of the sixteenth century; and, according to the traditions preserved at Cumana, the sea often inundated the shores, rising from fifteen to twenty fathoms. The inhabitants fled to the Cerro of San Antonio, and to the hill where now stands the small convent of St. Francis. It is even thought, that these frequent inundations induced the inhabitants to build that quarter of

* This was the first name given to the city of Cumana (Girolamo Benzoni, Hist. del Mondo nuovo, p. 3, 31, and 33). James Castellon arrived at St. Domingo in 1521, after the appearance of the celebrated Bartholomew de las Casas in these countries. On attentively reading the narratives of Benzoni and Caulin, we find that the fort of Castellon was built near the mouth of the Manzanares (alla ripa del fiume de Cumana); and not, as some modern travellers have asserted, on the mountain where now stands the castle of St. Antonio.

† Herera, Description de las Indias, p. 14.

the town, which is backed by the mountain, and stands on a part of its declivity.

As no record exists at Cumana, and its archives, on account of the continual devastations of the termites, or white ants, contain no document, that goes back farther than a hundred and fifty years, we are unacquainted with the precise dates of the ancient earthquakes. We only know, that, in times nearer our own, the year 1776 was at the same time the most fatal to the colonists, and the most remarkable for the natural history of the country. A drought, like those which are felt at times in the islands of Cape Verd, had reigned during fifteen months, when, on the 21st of October, 1766, the city of Cumana was entirely destroyed. The remembrance of this day is every year renewed by a religious festival, attended with a solemn procession. The whole of the houses were overturned in the space of a few minutes, and the shocks were hourly repeated during fourteen months. In several parts of the province the earth opened, and threw out sulphureous waters. These irruptions were very frequent in a plain extending toward Casanay, two leagues to the east of the town of Cariaco, and known by the name of the *hollow ground, tierra hueca*, because it appears entirely undermined by thermal springs. During the years 1766 and 1767, the inhabitants of Cumana encamped in the streets; and they began to rebuild their houses, when the earthquakes took

place only once a month. What was felt at Quito, immediately after the great catastrophe of the 4th of February, 1797, took place on these coasts. While the ground was in a state of continual oscillation, the atmosphere seemed to dissolve itself into water. The rivers were swollen by these sudden torrents of rain, the year was extremely fertile, and the Indians, whose frail huts easily resist the strongest shocks, celebrated from ideas of an old superstition, with feasting and dances, the destruction of the world, and the approaching epocha of its regeneration.

Tradition states, that in the earthquake of 1766, as well as in another very remarkable one in 1794, the shocks were mere horizontal oscillations; it was only on the disastrous day of the 14th of December, 1797, that for the first time at Cumana the motion was felt by the raising up of the ground. More than four fifths of the city were then entirely destroyed; and the shock, attended by a very loud subterraneous noise, resembled, as at Riobamba, the explosion of a mine at a great depth. Happily the most violent shock was preceded by a slight undulating motion, so that the greater part of the inhabitants could escape into the streets, and a small number only perished of those who had assembled in the churches. It is a generally received opinion at Cumana, that the most destructive earthquakes are announced by very feeble oscillations, and by a

hollow sound, which does not escape the observation of persons habituated to this kind of phænomenon. In this fatal moment, the cries of *misericordia, tembla, tembla* *, are every where heard; and it is very rarely, that a false alarm is given by a native. Those who are most fearful attentively observe the motions of dogs, goats, and swine. The last of these animals, endowed with delicate olfactory nerves, and accustomed to turn up the earth, give warning of approaching danger by their restlessness and their cries. We shall not decide, whether, placed nearer the surface of the ground, they are the first that hear the subterraneous noise; or whether their organs receive the impression of some gazeous emanation, which issues from the earth. We cannot deny the possibility of this latter cause. During my abode at Peru, a fact was observed in the inland country, which has an analogy with this kind of phænomenon, and which is not unfrequent. At the end of violent earthquakes, the herbs that cover the savannahs of Tucuman acquired noxious properties; an epidemic disorder took place among the cattle, and a great number among them appeared stupified or suffocated by the deleterious vapours exhaled from the ground.

At Cumana, half an hour before the catastrophe of the 14th of December, 1797, a strong

* Mercy! the earth trembles.

smell of sulphur was perceived near the hill of the convent of St. Francis; and on the same spot a subterraneous noise, which seemed to proceed from the south-east to the north-west, was heard the loudest. At the same time flames appeared on the banks of the Manzanares, near the hospice of the Capuchins, and in the gulf of Cariaco, near Mariguitar. This last phænomenon, so extraordinary in a country not volcanic, is pretty frequent in the Alpine calcareous mountains near Cumanacoa, in the valley of Bordones, in the island of Margaretta, and amidst the *Llanos* * or savannahs of New Andalusia. In these savannahs flakes of fire rise to a considerable height; they are seen for hours together in the dryest places; and it is asserted, that, on examining the ground which furnishes the inflammable matter, no crevice is to be found. This fire, which resembles the sources of hydrogen, or *Salse*, of Modena †, or what is called the Will o' the wisp of our marshes, does not burn the grass; because, no doubt the column of gaz, which developes itself, is mixed with azot, and carbonic acid, and does not burn at its basis. The people, although less superstitious here than in Spain, call these reddish flames by the singular name of the *soul*

* In the Mesa of Cari, to the north of Aguasay, and in the Mesa of Guanipa, far from the *Morichales*, which are the humid spots where the mauritia palm-tree grows.

† Brieslak, Geologia, t. ii, p. 284.

of the tyrant Aguirre; imagining, that the spectre of Lopez Aguirre, harassed by remorse, wanders over these countries sullied by his crimes *.

The great earthquake of 1797 produced some changes in the configuration of the shoal of Morro Roxo, toward the mouth of the Rio Bordones. Similar swellings were observed at the time of the total ruin of Cumana, in 1766. At this period, the Punta Delgado, on the southern coast of the gulf of Cariaco, was perceptibly enlarged; and in the Rio Guarapiche, near the village of Maturin, a shoal was formed, no doubt by the action of the elastic fluids, which displaced and raised up the bed of the river.

We shall not continue to describe with minuteness the local changes produced by the different earthquakes of Cumana. In order to follow a plan conformable to the end we proposed in this work, we shall endeavour to generalize our ideas, and comprehend in one point of view every thing

* When at Cumana, or in the island of Margaretta, the people pronounce the words *el tiranno* (the tyrant), it is always to denote the infamous Lopez d'Aguirre; who, after having taken part, in 1560, in the revolt of Ferdinando de Guzman against Pedrode Ursua, governor of the Omeguas and Dorado, gave himself the title of *traidor*, or traitor. He descended the river of the Amazons with his band, and reached by a communication of the rivers of Guyana, of which we shall hereafter speak, the island of Margaretta. The port of Paraguache still bears, in this island, the name of the Tyrant's Port.

that relates to these phænomena, so terrific, and so difficult to explain. If it be the duty of those natural philosophers, who visit the Alps of Switzerland, or the coasts of Lapland, to extend our knowledge respecting the glaciers and the aurora borealis, it may be expected, that a traveller, who has traversed Spanish America, should have chiefly fixed his attention on volcanoes and earthquakes. Each part of the Globe is an object of particular study; and when we cannot hope to penetrate the causes of natural phænomena, we ought at least to endeavour to discover their laws, and distinguish, by comparison of numerous facts, what is constant and uniform from what is variable and accidental.

The great earthquakes, which interrupt the long series of slight shocks, appear to have no regular periods at Cumana. They have taken place at intervals of fourscore, a hundred, and sometimes less than thirty years; while on the coasts of Peru, for instance at Lima, a certain regularity is observed in the periods of the total ruin of the city. The belief of the inhabitants in the existence of this uniformity has a happy influence on public tranquillity, and the encouragement of industry. It is generally admitted, that it requires a sufficiently long space of time for the same causes to act with the same energy; but this reasoning is just only in as much as the shocks are considered as a local phænomenon; and as a

particular focus, under each point of the Globe exposed to those great catastrophes, is admitted. Wherever new edifices are raised on the ruins of the old, we hear from those who refuse to build, that the destruction of Lisbon on the first of November, 1755, was soon followed by a second, and not less fatal, on the 31st of March, 1761.

It is a very old * and commonly received opinion at Cumana, Acapulco, and Lima, that a perceptible connection exists between earthquakes, and the state of the atmosphere that precedes these phænomena. On the coasts of New Andalusia, the inhabitants are alarmed, when, in excessively hot weather, and after long droughts, the breeze suddenly ceases to blow, and the sky, clear, and without clouds at the zenith, exhibits, near the horizon, at six or eight degrees elevation, the appearance of a reddish vapor. These prognostics are however very uncertain ; and when the whole of the meteorological variations, at the times when the Globe has been the most agitated, are called to mind, it is found, that violent shocks take place equally in dry and in wet weather; when the coolest winds blow, or during a dead and suffocating calm. From the great number of earthquakes, which I have witnessed to the

* Arist. Meteor., Lib. 2 (ed. Duval., t. i, p. 798). Seneca, Nat. Quæst., lib. vi, c. 12.

north and south of the equator; on the continent, and in the basin of the seas; on the coasts, and at 2500 toises height; it appears to me, that the oscillations are generally very independant of the previous state of the atmosphere. This opinion is embraced by a number of enlightened persons, who inhabit the Spanish colonies; and whose experience extends, if not over a greater space of the Globe, at least to a greater number of years, than mine. On the contrary, in parts of Europe where earthquakes are rare compared to America, natural philosophers are inclined to admit an intimate connection between the undulations of the ground, and certain meteors, which accidentally take place at the same epocha. In Italy, for instance, the sirocco and earthquakes are suspected to have some connection; and at London, the frequency of falling stars, and those southern lights*, which have

* Philos. Transact., vol 46, p. 642, 663, and 743. The appearance of these meteors led two distinguished men of science, nearly at the same time, to adopt theories diametrically opposite to each other. Hales, struck with his experiments on the decomposition of nitrous gas when it comes into contact with atmospheric air, invented a chemical theory, according to which, the earthquake was the effect "of a prompt condensation of sulphurous and nitrous exhalations." Ib. p. 678. Stukeley, familiar with Franklin's ideas of the distribution of electricity in the strata of the atmosphere, considered the oscillatory motion of the surface of the Globe as the effect of an electric shock propagated

since been often observed by Mr. Dalton, were considered as the forerunners of those shocks, which were felt from 1748 to 1756.

On the days when the earth is shaken by violent shocks, the regularity of the horary variations of the barometer is not disturbed under the tropics. I have verified this observation at Cumana, at Lima, and at Riobamba; and it is so much the more worthy of fixing the attention of natural philosophers, as at St. Domingo, at the town of Cape François, it is asserted, that a water barometer* was observed to sink two inches and a half immediately before the earthquake of 1770. In the same manner it is related, that, at the time of the destruction of Oran, a druggist fled with his family, because, observing accidentally, a few minutes before the earthquake, the height of the mercury in his barometer, he perceived, that the

from the air to the earth. Ib. p. 642. Each of these theories admitted the existence of a large black cloud separating strata of air unequally charged with electricity, or with nitrous vapours; and this cloud was seen at London at the moment of the first shocks. I mention these reveries, to show to what errors we expose ourselves in geology and physics, when, instead of taking into view the whole of the phænomena that occur, we suffer our attention to be arrested by accidental circumstances.

* Currejolles, in the Journal de Phys., tom. liv, p. 106. This depression answers only to two lines of mercury. The barometer remained motionless at Pignerol, in April, 1808. (Ibid., t. lxvii, p. 292.)

column sunk in an extraordinary manner. know not whether we can give credit to this assertion; but as it is nearly impossible to examine the variations of the weight of the atmosphere during the shocks, we must be satisfied in observing the barometer before or after these phænomena have taken place. In the temperate zone, the aurora borealis does not always modify the variation of the needle, and the intensity of the magnetic forces *. Perhaps also earthquakes do not act constantly in the same manner on the air that surrounds us.

We can scarcely doubt, that the earth, when opened and agitated by shocks, spreads occasionally gazeous emanations through the atmosphere, in places remote from the mouths of volcanoes not extinct. At Cumana, as we have already observed, flames and vapors mixed with sulphurous acid spring up from the most arid soil. In other parts of the same province, the earth ejects water and petroleum. At Riobamba a muddy and inflammable mass, which is called *moya*, issues from crevices that close again, and accumulates into elevated hills. At seven leagues

* I had an opportunity of observing, conjointly with Mr. Oltmanns at Berlin, on the night of the 20th of December, 1806, a change of magnetic intensity. The point of convergence of the rays of the Aurora borealis was determined astronomically by the azimuth of a star. (Gilbert's Annalen, 1811, p. 274.)

from Lisbon, near Colares, during the terrible earthquake of the first of November, 1755, flames and a column of thick smoke were seen to issue from the flanks of the rocks of Alvidras, and, according to some witnesses, from the bosom of the sea *. This smoke lasted several days, and it was the more abundant in proportion as the subterraneous noise, which accompanied the shocks, was louder.

Elastic fluids thrown into the atmosphere may act locally on the barometer, not by their mass, which is very small, compared to the mass of the atmosphere; but because, at the moment of the great explosions, an ascending current is probably formed, which diminishes the pressure of the air. I am inclined to think, that in the greater part of earthquakes nothing escapes from the agitated earth; and that, where gazeous emanations and vapours take place, they oftener acccompany, or follow, than precede the shocks. This last circumstance explains a fact, which seems indubitable, I mean that mysterious influence, in equinoctial America, of earthquakes on the climate, and on the order of the dry and rainy seasons. If the earth generally act on the air only at the moment of the shocks, we can conceive why it is so rare, that a sensible meteorological change becomes the presage of these great revolutions of nature.

* Phil. Trans., t. xlix, p. 414.

The hypothesis according to which, in the earthquakes of Cumana, elastic fluids tend to escape from the surface of the soil, seems confirmed by the observation of the dreadful noise, which is heard during the shocks at the borders of the wells in the *plain of Charas*. Water and sand are sometimes thrown out twenty feet high. Similar phænomena have not escaped the observation of the ancients, who inhabited parts of Greece and Asia Minor abounding with caverns, crevices, and subterraneous rivers. Nature, in its uniform progress, every where suggests the same ideas of the causes of earthquakes, and the means by which man, forgetting the measure of his strength, pretends to diminish the effect of the subterraneous explosions. What a great Roman naturalist has said of the utility of wells and caverns * is repeated in the New World by the most igno-

* In puteis est remedium, quale et crebri specus præbent: conceptum enim spiritum exhalant: quod in certis notatur oppidis, quæ minus quatiuntur, crebris ad eluviem cuniculis cavata. Plin. Lib. ii, c. 82 (ed. Par. 1725, t. i, p. 112). Even at present, in the capital of St. Domingo, wells are considered as diminishing the violence of the shocks. I shall observe on this occasion, that the theory of earthquakes, given by Seneca (Nat. Quæst., Lib. vi, c. 4—31), contains the germe of every thing that has been said in our times on the action of the elastic vapors confined in the interior of the Globe. (Compare Michell, in the Phil. Trans., t. li, p. 566—634; and Dr. Young in Rees's New Cyclopedia, Vol. xii, P. 2, art. EARTHQUAKE.)

rant Indians of Quito, when they show travellers the *guaicos*, or crevices of Pichincha.

The subterraneous noise, so frequent during earthquakes, is generally not in the ratio of the strength of the shocks. At Cumana it constantly precedes them, while at Quito, and for a short time past at Caracas, and in the West India Islands, a noise like the discharge of a battery was heard, a long time after the shocks had ceased. A third kind of phænomenon, the most remarkable of the whole, is the rolling of those subterraneous thunders, which last several months, without being accompanied by the least oscillating motion of the ground *.

In every country subject to earthquakes, the point where, probably by a particular disposition of the stony strata, the effects are the most sensible is considered as the cause and the focus of the shocks. Thus at Cumana the hill of the castle of St. Antonio, and particularly the eminence on which the convent of St. Francis is placed, are belived to contain an enormous quantity of sulphur, and other inflammable matter. We forget, that the rapidity with which the un-

* The subterraneous thunders *(bramidos y truenos subterraneos)* of Guanaxuato will be described in the course of this work. (Nouv. Esp., t. p. 47.) The phænomenon of a noise without shocks had already been observed by the ancients. (Aristot. Meteor. lib. ii, ed. Duval, p. 802. Plin. lib. ii, c. 80).

dulations are propagated to great distances, even across the basin of the ocean, proves, that the centre of action is very remote from the surface of the Globe. From this same cause no doubt earthquakes are not restrained to certain species of rocks, as some naturalists pretend, but all are fitted to propagate the movement. In order to keep within the limits of my own experience, I shall here cite the granites of Lima and Acapulco; the gneiss of Caracas; the mica-slate of the peninsula of Araya; the primitive thonschiefer of Tepecuacuilco, in Mexico; the secondary limestones of the Apennines, Spain, and new Andalusia; and finally the trappean porphyries of the provinces of Quito, and Popayan*. In these different places the ground is frequently agitated by the most violent shocks; but sometimes, in the same rock, the superior strata form invincible obstacles to the propagation of the motion. Thus, in the mines of Saxony†, we have seen workmen hasten up affrighted by oscillations, which were not felt at the surface of the ground.

If, in regions the most remote from each other, primitive, secondary, and volcanic rocks, share

* I might have added to the list of secondary rocks the gypsum of the newest formation, for instance that of Montmartre placed on a marine calcareous rock, which is posterior to the chalk. See the Mém. de l'Académie, t. i, p. 341, on the earthquake felt at Paris, and in its environs in 1681.

† At Marienburgh in the Erzgebuerge.

equally in the convulsive movements of the Globe; we cannot but admire also, that, in ground of little extent, certain classes of rocks oppose themselves to the propagation of the shocks. At Cumana, for instance, before the great catastrophe of 1797, the earthquakes were felt only along the southern and calcareous coast of the gulf of Cariaco, as far as the town of this name; while in the peninsula of Araya, and at the village of Maniquarez, the ground did not partake of the same agitation. The inhabitants of this northern coast, which is composed of mica-slate, built their huts on a motionless earth; a gulf three or four thousand toises in breadth separated them from a plain covered with ruins, and overturned by earthquakes. This security, founded on the experience of several ages, has vanished; and since the 14th of December, 1797, new communications appear to have been opened in the interior of the Globe. At present the peninsula of Araya is not merely subject to the agitations of the soil of Cumana, the promontory of mica-slate is become in its turn a particular centre of the movements. The earth is sometimes strongly shaken at the village of Maniquarez, when on the coast of Cumana the inhabitants enjoy the most perfect tranquillity. The gulf of Cariaco nevertheless is only sixty or eighty fathoms deep.

It has been thought from observations made

both on the continent and in the islands, that the western and southern coasts are most exposed to shocks*. This observation is connected with the ideas which geologists have long formed of the position of the high chains of mountains, and the direction of their steepest declivities; the existence of the Cordillera of Caracas, and the frequency of the oscillations on the eastern and northern coast of Terra Firma, in the gulf of Paria, at Carupano, at Cariaco, and at Cumana, are proofs of the uncertainty of this opinion.

In New Andalusia, as well as in Chili and Peru, the shocks follow the course of the shore; and extend but little inland. This circumstance, as we shall soon find, indicates an intimate connection between the causes that produce earthquakes and volcanic eruptions. If the earth was most agitated on the coasts, because they are the lowest part of the land, why should not the oscillations be equally strong and frequent on those vast savannahs or meadows †, which are scarcely eight or ten toises above the level of the ocean?

The earthquakes of Cumana ‡ are connected with those of the West India islands; and it has even

* Courrejolles, in the Journ. de Phys., t. liv, p. 104.

† The *Llanos* of Cumana, of New Barcelona, of Calabozo, of Apura, and of Meta.

‡ See my Geological Table of South America, Journ. de Physique, t. liii, p. 58.

been suspected, that they have some connection with the volcanic phænomena of the Cordilleras of the Andes. On the 4th of November, 1797, the soil of the province of Quito underwent such a destructive commotion, that, notwithstanding the extreme feebleness of the population of that country, near 40000 natives perished, buried under the ruins of their houses, swallowed up in the crevices, or drowned in lakes that were suddenly formed. At the same period, the inhabitants of the eastern Antilles were alarmed by shocks, which continued during eight months, when the volcano of Guadaloupe threw out pumice stones, ashes, and gusts of sulphureous vapors. This eruption of the 27th of September, during which very long-continued subterraneous noises were heard*, was followed on the 14th of December by the great earthquake of Cumana. Another volcano of the West India islands, that of St. Vincents†, has lately given a

* Report made to the generals Victor Hugues and Lebas, by Amie, Peyre, Hapel, Fontelliau, and Codé, appointed to examine the situation of the volcano of Basse-Terre, and the effects that had taken place in the night, from the seventh to the eighth of Vendemiaire, in the year 6 : p. 46. This narrative of a journey to the top of the volcano, contains several curious observations ; it was printed at Guadaloupe in 1798.

† Letter from Mr. Hamilton to Sir Joseph Banks, 1813. The eruption began on the 30th of April, 1812 ; it was preceded by repeated earthquakes during eleven months. (Phil. Trans. for 1785, p. 16.)

fresh instance of these extraordinary connections. This volcano had not emitted flames since 1718, when they burst forth anew, in 1812. The total ruin of the city of Caracas* preceded this explosion thirty-five days, and violent oscillations of the ground were felt, both in the islands, and on the coasts of Terra Firma.

It has long been remarked, that the effects of great earthquakes extend much farther than the phænomena arising from burning volcanoes. In studying the physical revolutions of Italy, carefully examining the series of the eruptions of Vesuvius and Etna, we can scarcely recognize, notwithstanding the proximity of these mountains, any traces of a simultaneous action. It is on the contrary doubtless, that at the period of the last and preceding destruction of Lisbon†, the sea was vio-

* The 26th of March, 1812.

† The 1st of November 1755, and 31st of March 1761. During the first of these three earthquakes, the ocean inundated, in Europe, the coasts of Sweden, England, and Spain; in America, the islands of Antigua, Barbadoes, and Martinico. At Barbadoes, where the tides rise only from 24 to 28 inches, the water rose twenty feet in Carlisle Bay. It became at the same time "as black as ink;" because, without doubt, it was mixed with the petroleum, or asphaltum, which abounds at the bottom of the sea, as well on the coasts of the gulf of Cariaco, as near the island of Trinidad. In the West Indies, and in several lakes of Switzerland, this extraordinary motion of the waters was observed six hours after the first shock that was felt at Lisbon. (Phil. Trans.,

lently agitated even as far as the New World, for instance, at the island of Barbadoes, more than twelve hundred leagues distant from the coasts of Portugal.

Several facts tend to prove, that the causes

vol. xlix, p. 403, 410, 544, 668; ibid., vol. lii, p. 424.) At Cadiz a mountain of water sixty feet high was seen eight miles distant at sea; this mass threw itself impetuously on the coasts, and beat down a great number of edifices; like the wave fourscore and four feet high, which, on the 9th of June, 1586, at the time of the great earthquake of Lima, covered the port of Callao. (Acosta, Hist. natural de las Indias, ed. de 1591, p. 123.) In North America, on Lake Ontario, strong agitations of the water were observed, from the month of October 1755. These phænomena are proofs of subterraneous communications at enormous distances. On comparing the epochas of the great catastrophes of Lima and Guatimala, which generally succeed each other at long intervals, it has sometimes been thought, that the effect of an action slowly propagating itself along the Cordilleras, sometimes from north to south, at other times from south to north, may be perceived. (Cosme Bueno, Descripcion del Peru, ed. de Lima, p. 67.) The following are four of these remarkable epochas.

Mexico.	Peru.
(Lat. 13° 32′ north.)	(Lat. 12° 2′ south.)
30th of Nov. 1577.	17th of June, 1578.
4th of March, 1679.	17th of June, 1678.
12th of Feb. 1689.	10th of Oct. 1688.
27th of Sept. 1717.	8th of Feb. 1716.

When the shocks are not simultaneous, or do not follow at short intervals, great doubts may be entertained with respect to the pretended communication of the movement.

which produce earthquakes have a near connection with those that act in volcanic eruptions*. We learnt at Pasto, that the column of black and thick smoke, which, in 1797, issued for several months from the volcano near this shore, disappeared at the very hour, when, sixty leagues to the south, the towns of Riobamba, Hambato, and Tacunga were overturned by an enormous shock. When, in the interior of a burning crater, we are seated near those hillocks formed by ejections of scoriæ and ashes, we feel the motion of the ground several seconds before each partial eruption takes place. We observed this phænomenon at Vesuvius in 1805, while the mountain threw out scoriæ at a white heat; we were witnesses of it in 1802, on the brink of the immense crater of Pichincha,

* The connection of these causes, already known to the ancients, excited fresh attention at the period of the discovery of America. (Acosta, p. 121.) This discovery not only offered new productions to the curiosity of men, it gave also extent to their ideas on physical geography, on the varieties of the human species, and the migrations of nations. It is impossible to read the first narratives of the Spanish travellers, especially those of the Jesuit Acosta, without perceiving with surprise the influence which the aspect of a great continent, the study of extraordinary appearances of nature, and an intercourse with men of different races, have exerted on the progress of knowledge in Europe. The germe of a great number of physical truths is found in the works of the sixteenth century; and this germe would have fructified, had it not been crushed by fanaticism and superstition.

from which nevertheless at that time clouds of sulphureous acid vapours only issued.

Every thing in earthquakes seems to indicate the action of elastic fluids seeking an outlet to spread themselves in the atmosphere. Often, on the coasts of the South Sea, the action is almost instantaneously communicated from Chili to the gulf of Guayaquil, a distance of six hundred leagues; and, what is very remarkable, the shocks appear to be so much the stronger, as the country is more distant from burning volcanoes. The granitic mountains of Calabria, covered with very recent breccia, the calcareous chain of the Apennines, the country of Pignerol, the coasts of Portugal and Greece, those of Peru and Terra Firma, afford striking proofs of this assertion*. The Globe, it may be said, is agitated with greater force, in proportion as the surface has a smaller number of funnels communicating with the caverns of the interior. At Naples and at Messina, at the foot of Cotopaxi and of Tunguragua, earthquakes are dreaded only when vapours and flames do not issue from the crater. In the kingdom of Quito, the great catastrophe of Riobamba, which we have before mentioned, has led several well-informed persons to think, that this unfortunate country would be less often desolate, if the subterraneous fire should break the porphyritic dome

* Fleuriau de Bellevue, Journ. de Phys., t. lxii, p. 261.

of Chimborazo; and if this colossal mountain should become a burning volcano. At all times analogous facts have led to the same hypothesis. The Greeks, who, like ourselves, attributed the oscillations of the ground to the tension of elastic fluids, cited in favour of their opinion the total cessation of the shocks at the island of Eubœa, by the opening of a crevice in the Lelantine plain*.

We have endeavoured to collect at the end of this chapter the general phænomena of earthquakes under different climates. We have shown, that subterraneous vapours are subjected to laws as uniform as the mixture of gazeous fluids, which constitutes our atmosphere. We have abstained from all discussion of the nature of the chemical agents, which are the causes of the great derangements that the surface of the earth undergoes from time to time. It is sufficient here to observe, that these causes are concealed at immense depths; and that we must seek them in the rocks which we call primitive, perhaps even below the earthy and oxided crust of the Globe, in the abysses that contain the metalloidal bases of silex, lime, soda, and potash.

The phænomena of volcanoes, and those of earthquakes, have been considered of late as the

* The shocks ceased only when a crevice, which ejected a "river of fiery mud," opened in the plain of Lelantum, near Chalcis. Strabo, lib. 1, ed. Oxon., 1807, t. i, p. 85. (See also the translation by M. du Theil, t. i, p. 137, note 4.)

effects of voltaic electricity, developed by a particular disposition of heterogeneous strata. It cannot be denied, that often, when violent shocks succeed each other in the space of a few hours, the electricity of the air* sensibly increases at the instant the ground is most agitated; but in order to explain this phenomenon, it is unnecessary to recur to an hypothesis, which is in direct contradiction to every thing that has hitherto been observed respecting the structure of our planet, and the disposition of its strata.

* See the electroscopical experiments made in Piedmont, in the valleys of Pelis and Clusson, in 1808. Journal de Phys., t. 67, p. 292.

CHAPTER V.

Peninsula of Araya.—Salt-marshes.—Ruins of the Castle of San Giacomo.

The first weeks of our abode at Cumana were employed in verifying our instruments, in herbalizing in the neighbouring fields, and in examining the traces of the earthquake of the 14th of December, 1797. Overpowered at once by a great number of objects, we were somewhat embarrassed to lay down a regular plan of study and observation. If every thing around us was fitted to inspire us with the most lively interest, our physical and astronomical instruments in their turns excited strongly the curiosity of the inhabitants. We were distracted by frequent visits; and in order not to dissatisfy persons, who appeared so happy to see the spots of the Moon through Dollond's telescope, the absorption of two gazes in a eudiometrical tube, or the effects of galvanism on the motions of a frog, we were obliged to answer questions often obscure, and repeat for whole hours the same experiments.

These scenes were renewed for the space of five years, every time that we took up our abode in a

place where it was understood, that we were in possession of microscopes, telescopes, and electrical apparatus. They were in general so much the more fatiguing, as the persons who visited us had confused notions of astronomy and physicks; two sciences, which in the Spanish colonies are designated under the singular name of the new philosophy, *nueva filosophia*. The half-scientific looked on us with a sort of disdain, when they learnt that we had not brought in our collection of books the *Spectacle de la Nature* by Abbé Pluche, the *Cours de Physique* of Sigaud la Fond, or the Dictionary of Valmont de Bomare. These three works, and the *Traité d'Economie politique* of Baron Bielfeld, are the foreign work smost known and esteemed in Spanish America, from Caracas and Chili to Guatimala and the north of Mexico. No one is thought learned, who cannot quote their translations; and it is only in the great capitals, at Lima, at Santa Fe de Bogota, and at Mexico, that the names of Haller, Cavendish, and Lavoisier, begin to take the place of those, that have enjoyed popular celebrity for these fifty years past.

The curiosity excited respecting the phænomena of the heavens, and various objects of the natural sciences, takes a very different character among anciently civilized nations, and among those who have made but little progress in the unfolding of their intellectual faculties. Each of them exhibits in the highest classes of society frequent examples

of persons unacquainted with science; but in the colonies, and among new people, curiosity, far from being idle or transient, arises from an ardent desire of instruction, and discovers itself with an ingenuousness and simplicity, which in Europe are the characteristics only of youth.

I could not begin a regular course of astronomical observations before the 28th of July, though it was highly important for me to know the longitude given by Berthoud's time-keeper; but it happened, that in a country, where the sky is constantly clear and serene, no stars appeared for several nights. Every day, two hours after the Sun had passed the meridian, a storm gathered; and I had great difficulty in obtaining correspondent altitudes of the Sun, though I took three or four sets at different intervals. The chronometrical longitude of Cumana differed only four seconds in time from that which I deduced from the celestial phænomena; yet our voyage had lasted more than forty days, and during the excursion to the top of the Peak of Teneriffe, the watch had been exposed to great variations of temperature *.

From the whole of the observations † which I made in 1799 and 1800 it follows, that the latitude of the great square at Cumana is

* Astron. Observ. vol. i, p. xxiv.

† Ibid, vol. i, p. 42 to 92.

10° 27′ 52″, and its longitude 66° 30′ 2″. This longitude is founded on the difference of time, on lunar distances, on the eclipse of the Sun on the 28th of October, 1799, and on ten immersions of Jupiter's satellites, compared with observations made in Europe. It differs very little from that which Mr. Fidalgo had obtained before me, but only by mere chronometrical means. The oldest chart which we have of the Continent, that of Don Diego Ribeiro, geographer to the emperor Charles the Fifth, places Cumana in latitude 9° 30′*; which differs fifty-eight minutes from the real latitude, and half a degree from that marked by Jefferies in his American Pilot, published in 1794. During three centuries the whole of the coast of Terra Firma has been laid down too far to the south: this has been owing to the current near the island of Trinidad, which sets toward the north, and mariners are led by their dead-reckoning, to think themselves farther South than they really are.

On the 17th of August a halo, or luminous circle, round the Moon, fixed the attention of the inhabitants, who considered it as the presage of some violent earthquake; for, according to the physical notions of the people, all extraordinary

* According to Herera, latitude 9° 50′ (Descripcion de las Indias Occid. p. 9). According to the Carte de l'Océan Atlantique, publiée au Dépôt de la Marine en 1792, latitude 9° 52′. The chart of Ribeiro is of the year 1529.

phænomena are immediately connected with each other. Coloured circles around the Moon are much more rare in the countries of the north, than in Provence, Italy, and Spain. They are seen particularly, and this fact is singular enough, when the sky is clear, and the weather seems to be most fair and settled. Under the torrid zone beautiful prismatic colours appear almost every night, even at the time of the greatest droughts: often in the space of a few minutes they disappear several times, because, without doubt, the superior currents change the state of the floating vapours, by which the light is refracted. I sometimes even observed, between the fifteenth degree of latitude and the equator, small haloes around the planet Venus; the purple, orange, and violet, were distinctly perceived; but I never saw any colours around Sirius, Canopus, or Acherner.

While the halo was visible at Cumana, the hygrometer noted great humidity; nevertheless the vapours appeared so perfectly in solution, or rather so elastic and uniformly disseminated, that they did not alter the transparency of the atmosphere. The Moon arose after a storm of rain, behind the castle of St. Antonio. As soon as she appeared on the horizon, we distinguished two circles; one large and whitish, forty-four degrees in diameter; the other a small circle of 1° 43′, displaying all the colours of the rainbow. The space between the two circles was of the deepest azure. At four

degrees height, they disappeared, while the meteorological instruments indicated not the slightest change in the lower regions of the air. This phænomenon had nothing extraordinary, except the great brilliancy of the colors, added to the circumstance, that, according to the measures taken with Ramsden's sextant, the lunar disk was not exactly in the centre of the haloes. Without this actual measurement, we might have thought, that the excentricity was the effect of the projection of the circles on the apparent concavity of the sky *.

* The 17th of August, 1799: thermometer, 25° 3′; Deluc's hygrometer, 68°. The altitude of the Moon being 11° 8′, the horizontal diameter of the little corona was 1° 50′, and its vertical diameter 1° 43′. The distance from the centre of the Moon to the upper edge of the small halo was forty-one minutes, and to the lower edge fifty-nine minutes. The whole space between the lunar disk and the extremity of the small halo shone with prismatic colours. The horizontal diameter of the large white halo was 42° 3′. When the Moon had attained the altitude of 37° 34′ above the horizon, the diameter of the greater halo was 44° 10′, and the breadth of the milky band 3° 35′. The Moon no longer showed any excentricity, and the small halo had only 1° 27′ diameter. These measures were taken without a telescope, and by bringing with the sextant the edge of the Moon into contact with the very well defined extremities of both haloes. It seemed to me difficult to admit my being deceived nineteen minutes with respect to the excentricity of the Moon: the refraction would have rather diminished than have augmented the extent of the halo toward the lower edge. We must not confound this phænomenon, which belongs to the last strata

The form of the haloes, and the colors of the atmosphere of the tropics enlightened by the Moon, are worthy of new researches on the part of natural philosophers. At Mexico, in extremely fine weather, I have seen large bands*, having all the colours of the rainbow, spread along the vault of the sky, and converging toward the lunar disk; a curious meteor, which reminds us of that described by Mr. Cotes † in 1716.

If the situation of our house at Cumana was highly favourable for the observation of the stars and meteorological phænomena, it obliged us to be sometimes the witnesses of afflicting scenes in the day. A part of the great square is surrounded with arcades, above which is one of those long wooden galleries, which are common in warm countries. This was the place where slaves, brought from the coast of Africa, were sold. Of all the European governments Denmark was the first, and for a long time the only power, that

of the atmosphere, and which is observed in a clear sky without any visible vapours, with those coloured circles, which are projected on the white clouds driven by the wind before the lunar disk, and which have only seven or eight hundred toises of absolute height. (See Gibbes Walker Jordan, in Nicholson's Journ., 4to. ed., vol. iv, p. 141; and Newton's Optics, 1722, p. 476.)

* The night of the 8th of May, 1813.

† Smith's Optics, French translation, 1767, t. i, p. 173, §. 109, and p. 121, §. 169.

abolished the trade; notwithstanding which, the first negroes we saw exposed for sale had been landed from a Danish slave-ship. What are the duties of humanity, national honour, or the laws of his country, to a man stimulated by the speculations of sordid interest?

The slaves exposed to sale were young men from fifteen to twenty years of age. Every morning cocoa-nut oil was distributed among them, with which they rubbed their bodies, to give their skin a black polish. The persons who came to purchase examined the teeth of these slaves, to judge of their age and health; forcing open their mouths as we do those of horses in a market. This degrading custom dates from Africa, as is proved by the faithful picture, which, in one of his dramatic pieces *, Cervantes, released from his long captivity among the Moors, has drawn of the sale of the Christian slaves at Algiers. It is distressing to think, that even at this day there exist European colonists in the West Indies, who mark their slaves with a hot iron, to know them again if they escape. This is the treatment bestowed on those, "who save other men the trouble of sowing, tilling, and reaping, in order to live †."

* El Trato de Argel. Jorn. II (Viage al Parnasso, 1784, p. 316).

† La Bruyère, Caractères, Chap. XI. (ed. 1765, p. 300). I wish to cite at length a passage, in which the love of the human species is drawn with force, or rather with noble

The greater the impression which the first sale of negroes made on us, the more we congratulated ourselves on living among a people, and on a continent, where this sight is rare, and where the number of slaves is in general very inconsiderable. The number in 1800 did not exceed six thousand in the two provinces of Cumana and Barcelona, when at the same period the whole population was estimated at one hundred and ten thousand inhabitants. The trade in African slaves, which the Spanish laws have never favored, is almost nothing on coasts, where the trade in American slaves was carried on in the sixteenth century with a desolating activity. Macarapan, anciently called Amaracapana, Cumana, Araya, and particularly New Cadiz, built on the islet of Cubagua, might then be considered as commercial establishments to facilitate the trade. Girolamo Benzoni of Milan, who at the age of twenty-two years, had gone over to Terra Firma, took part in some expeditions made in 1542 to the coasts of Bordones, Cariaco, and Paria, to carry off the unfortunate natives. He relates with

severity. "We find (under the torrid zone) certain wild animals, male and female, scattered through the country, black, livid, and all over scorched by the Sun, bent to the earth which they dig and turn up with invincible perseverance. They have something like an articulate voice; and, when they stand up on their feet, they exhibit a human face, and in fact these creatures are men."

[illegible], and often with a sensibility not com- [illegible] the historians of that time, the examples of cruelty, of which he was a witness. He saw the slaves dragged to New Cadiz, to be marked on the forehead and on the arms, and to pay the *quint* to the officers of the crown. From this port the Indians were sent to the island of Hayti *, or St. Domingo, after having often changed masters, not by way of sale, but because the soldiers played for them at dice.

The first excursion we made was directed toward the peninsula of Araya, and those countries formerly too much celebrated for the slave-trade and pearl-fishery. We embarked on the Rio Manzanares, near the Indian suburb, on the 19th of August, about two in the morning. The principal object of this excursion was to see the

* "Noi pigliammo dugento e quaranta schiavi fra maschi e femine, piccoli e grandi. Cosa veramente molto compassionevole da vedera la condutta di quelle meschine creature, nude, stanche, stropiate. Le infelici madri con due e tre figliuoli su le spalle e in collo, colme di pianto e di dolore, afflitte, legati tutti da corde e di catene di ferro al collo, alle braccia, e alle mani. Si conducono a Cubagua e tutti si marchiano in faccia e su le braccia con ferro infocato, segnato d'un C; poi gli capitani ne fanno parte a soldati, che gli vendono, o se gli giuocano l'uno con altro. Se paga il quinto delle perle, del oro e dei schiavi a gli ufficiali del Re." Benzoni, Hist. del Mondo Nuovo., 1565, p. 4, 7, and 9. It was thus that the Phœnicians and Carthaginians formerly sought for slaves in Europe. Heyne, Opuscula, t. iii, p. 63.

ruins of the Castle of Araya, to examine the salt-works, and make a few geological observations on the mountains, that form the narrow peninsula of Maniquarez. The night was delightfully cool; swarms of phosphorescent insects* glittered in the air, and over a soil covered with sesuvium, and groves of mimosa, that bordered the river. We know how common the glow-worm † is in Italy, and in all the south of Europe; but the picturesque effect it produces cannot be compared to those innumerable, scattered, and moving lights, that embellish the nights of the torrid zone, and seem to repeat on the earth, along the vast extent of the savannahs, the spectacle of the starry vault of the sky.

When, on descending the river, we drew near some plantations, or *charas*, we saw bonfires kindled by the negroes; a light and undulating smoke rose to the tops of the palm-trees, and gave a reddish color to the disk of the Moon. It was on a Sunday night, and the slaves were dancing to the noisy and monotonous music of the guitar. The people of Africa, of negro race, have an inexhaustible store of activity and gayety in their character. After having passed through the painful labors of the week, the slaves, on days of festival, prefer the sounds of music, and the dance,

* Elater noctilucus.

† Lampyris italica, l. noctiluca.

to listless sleep. Let us not blame this mixture of carelessness and levity, which softens the bitterness of a life full of pains and sorrows!

The bark in which we passed the Gulf of Cariaco was very spacious. Large skins of the jaguar, or American tiger, were spread for our repose during the night. We had scarcely been two months under the torrid zone, and our organs were already become so sensible to the smallest variation of temperature, that the cold prevented us from sleeping; while to our surprise we saw that the centigrade thermometer was as high as 21·8°. This observation, well known to those who have lived a long time in the Indies, is worthy the attention of physiologists. Bouguer relates, that, when he reached the summit of Montagne Pelée, in the island of Martinico, he and his companion shook with cold, though the heat was above 21·5 degrees *. In reading the inte-

* Figure de la Terre, p. liv. The height of this summit is 736 toises, according to Dupuget; and 666 toises, according to M. Le Blond. This elevation consequently is not considerable enough, to cause a feeling of cold, as at Chimborazo and Pichincha, by the smaller quantity of oxygen inhaled by the lungs from a dilated air. If the barometer (at 16·2° temperature) keeps at the top of the Montagne Pelée at 24 inches 2 lines (*Le Blond, Voy. aux Antilles et dans l'Amérique Méridionale*, t. i, p. 87), the absolute height of this point is 660 toises, according to the rule of M. Laplace; supposing at the level of the sea the height of the mercury 28 inches 1 line, and the thermometer at twenty-five degrees.

resting narrative of Captain Bligh, who, in consequence of a mutiny on board the Bounty, was forced to make a voyage of twelve hundred leagues in an open boat, we see, that this navigator, in the tenth and twelfth degrees of south latitude, suffered much more from cold than from hunger*. During our abode at Guayaquil, in the month of January, 1803, we observed, that the natives covered themselves, and complained of the cold, when the thermometer sunk to 23·8°, while the heat appeared suffocating at 30·5°. Six or seven degrees were sufficient to cause the opposite sensations of cold and heat, because on these coasts of the South Sea the habitual temperature of the atmosphere is twenty-eight degrees. The humidity, which modifies the conducting power of the air for heat, contributes greatly to these impressions. In the port of Guayaquil, as every where else in the low regions of the torrid zone, the weather grows cool only from storms of rain: and I have observed, that, when the thermometer sinks to 23·8°, De Luc's hygrometer keeps up

* Bligh's Voyage to the South Sea, translated by Soulés, p. 265 and 316. The crew in the boat were often wet by the waves; but we know, that in this latitude, the temperature of the sea water cannot be below twenty-three degrees, and that the cold produced by evaporation is inconsiderable during the night, when the temperature of the air seldom exceeds twenty-five degrees.

to fifty and fifty-two degrees *; it is, on the contrary, at thirty seven degrees † in a temperature of 30·5°. At Cumana, in very heavy showers, we hear in the streets; *que hielo! estoy emparamado* ‡; though the thermometer exposed to the rain sinks only to 21·5°. From the whole of these observations it follows, that between the tro-

* 85·8 and 86·4° of Saussure's hygrometer.

† 73° Saussure.

‡ "*What an icy cold! I shiver as if I was on the top of the mountains.*" The provincial word *emparamarse* can be translated only by a very long periphrasis. *Paramo*, in Peruvian *puna*, is a denomination found on all the maps of Spanish America. In the colonies it signifies neither a desert nor a heath, but a mountainous place covered with stunted trees, exposed to the winds, and in which a damp cold perpetually reigns. Under the torrid zone, the paramoes are generally from one thousand six hundred to two thousand toises high. Snow often falls on them, but it remains only a few hours; for we must not confound, as geographers often do, the words *páramo* and *puna* with that of *nevado*, in Peruvian *ritticapa*, a mountain which enters into the limits of the perpetual snows. These notions are highly interesting to geology, and the geography of plants; because, in countries where no height has been measured, we may form an exact idea of the *least height* to which the Cordilleras rise, in looking into the map for the words *paramo* and *nevado*. As the *paramoes* are almost continually enveloped in a cold and thick fog, the people say, at Santa Fé, and at Mexico, *cae un paramito*, when a thick small rain falls, and the temperature of the air sinks considerably. From *paramo* has been made *emparamarse*, to be as cold as if we were on the ridge of the Andes.

pics, in plains where the temperature of the air is in the day time almost invariably above twenty-seven degrees, warmer clothing during the night is requisite, whenever in a damp air the thermometer sinks four or five degrees.

We landed, about eight in the morning, at the point of Araya, near the new salt-works. A solitary house stands in a plain destitute of vegetation, near a battery of three guns, which is the only defence of this coast, since the destruction of the fort of St. James's. The inspector of the salt-works passes his life in a hammock, whence he issues his orders to the workmen: a boat belonging to the king *(la lancha del re)* brings him every week his provision from Cumana. It is surprising, that a salt-work, which formerly excited the jealousy of the English, Dutch, and other maritime powers, has not given rise to a village, or even a farm; a few huts only of poor Indian fishermen are found at the extremity of the point of Araya.

We see at the same time, from this spot, the islet of Cubagua, the lofty hills of Margaretta, the ruins of the castle of St. Jago, the Cerro de la Vela, and the calcareous chain of the Bergantin, which bounds the horizon toward the south. I availed myself of this view, to take the angles between these different points, from a basis of four hundred toises, which I measured between the battery and the hill called the *Penna.* As the Cerro de la Vela, Bergantin, and the castle of St.

Antonio at Cumana, are equally visible from the Punta Arenas, situate to the west of the village of Maniquarez, the same objects were employed for an approximate determination of the respective positions of several points, which are laid down in the mineralogical chart of the peninsula of Araya. It follows from these data, that the mere of the old salt-works is nearly in 10° 33′. The difference of longitude between Cumana and the new salt-works is, according to Mr. Fidalgo, 5′ 34″. I found the same difference by the time-keeper*. The horary angles were exact to three or four seconds nearly; but I have no confidence in the chronometrical result, because the difference of time amounted only to a few seconds, and the gain of the watch on mean time at Cumana could not be verified immediately after my return, but only four days later.

The abundance of salt† contained in the peninsula of Araya was already known to Alonzo Ninno‡, when, following the steps of Columbus, Ojeda, and Amerigo Vespucci, he visited these countries in 1499. Though of all the people on the Globe the natives of America are those who consume the least salt, because they scarcely eat any thing but vegetables, it nevertheless ap-

* Astron. Observ. vol. i, p. 6, No. 17.

† Muriat of soda.

‡ Caulin, Hist. chorografica, p. 123.

pears, that the Guayquerias already dug into the clayey and muriatiferous soil of *Punta Arenas*. Even the brine-pits, which are now called *new*, and which are situate at the extremity of Cape Araya, had been worked at very early periods. The Spaniards settled at first at Cubagua, and soon after on the coasts of Cumana, worked from the beginning of the sixteenth century the salt marshes, which stretch away in the form of a mere to the north of Cerro de la Vela. As at that period the peninsula of Araya had no settled population, the Dutch availed themselves of the natural riches of a soil, which appeared a property common to all nations. In our days, each colony has its own salt-works, and navigation is so much improved, that the merchants of Cadiz can send at small expense salt from Spain and Portugal to the southern hemisphere, a distance of 1900 leagues, to cure meat at Monte Video and Buenos Ayres. These advantages were unknown at the time of the conquest; colonial industry had then made so little progress, that the salt of Araya was carried at great expense to the West India islands, Carthagena and Portobello*. In 1605, the court of Madrid sent armed ships to Punta Araya, with orders to station themselves there, and expel the Dutch by force of arms. The Dutch, however,

* MSS. of the archives of Cumana. (*Informes hechos sobre la Salina nueva.*)

continued to carry on a contraband trade in salt, till, in 1622, a fort was built near the salt-works, that afterward became celebrated under the name of the Castillo de Santiago, or of the Real Fuerza de Araya. The great salt-marshes are laid down on the oldest Spanish maps, sometimes as a bay, and at other times as a mere. Laet, who wrote his *Orbis Novus* in 1633, and who had some excellent notions respecting these coasts, expressly states, that the mere was separated from the sea by an isthmus above the level of high water. In 1726, an extraordinary event destroyed the salt-works of Araya, and rendered the fort, the construction of which had cost more than a million of piastres, useless. An impetuous hurricane took place, which was a very rare phænomenon in these regions, where the sea is in general as calm as the water in our large rivers. The waves overflowed the land to a great extent; and by the effect of this eruption of the ocean the salt lake was converted into a gulf several miles in length. Since this period, artificial reservoirs, or pits, *(vasets)* have been formed, to the north of the range of hills which separates the castle from the north coast of the peninsula.

The consumption of salt amounted in 1799 and 1800, in the two provinces of Cumana* and Bar-

* At the period of my voyage the government of Cumana comprehended the two provinces of New Andalusia and New

celona, to nine or ten thousand *fanegas*, each sixteen *arrobas*, or four hundred weight. This consumption is very considerable, and gives, if we deduct from the total population fifty thousand Indians, who eat very little salt, sixty pounds for each person. In France, according to Mr. Necker, twelve or fourteen pounds only are reckoned; and this difference must be attributed to the quantity of salt employed in curing meat. Salt beef, called *tasajo*, is the most important article of export from Barcelona. Of nine or ten thousand *fanegas* furnished by the two provinces united, three thousand only are produced by the salt-works of Araya; the rest is extracted from the sea-water at the Morro of Barcelona, at Pozuelos, at Piritu, and in the Golfo Triste. In Mexico, the salt lake of Pennon Blanco alone furnishes yearly

Barcelona. The words *province* and *gorierno*, or *government*, of Cumana, are consequently not synonimous. A Catalan, Juan de Urpin, who had been by turns a canon, doctor of laws, counsellor at law in St. Domingo, and private soldier in the castle of Araya, founded, in 1636, the city of New Barcelona, and attempted to give the name of New Catalonia (Nueva Cathalunna) to the province, of which this newly constructed city became the capital. This attempt was fruitless; and it is from the capital that the whole province took its name. Since my departure from America, it has been raised to the rank of a *Govierno*. In New Andalusia, the Indian name of Cumana has prevailed over those of *Nueva Toledo* and *Nueva Cordoba*, which we find on the maps of the seventeenth century.

more than two hundred and fifty thousand *fanegas* of unpurified salt*.

The province of Caraccas possesses fine salt-works at *Los Roques;* that which formerly exist-at the small island of *Tortuga,* where the soil is strongly impregnated with muriat of soda, was destroyed by order of the Spanish government. A canal was made, by which the sea has free access to the salt-marshes. Foreign nations, who have colonies in the West Indies, frequented this uninhabited island; and the court of Madrid, from views of suspicious policy, was apprehensive, that the salt-works of Tortuga would have given rise to settlements, by means of which an illicit trade would have been carried on with Terra Firma.

The royal administration of the salt-works of Araya dates only from the year 1792. Before that period they were in the hands of Indian fishermen, who manufactured salt at their pleasure, and sold it, paying the government the moderate sum of three hundred piastres. The price of the fanega was then four reals†; but the salt was extremely impure, gray, mixed with earthy parti-

* New Spain, vol. ii, p. 562 and 595.

† In this narrative, as well as in the Political Essay on New Spain, all the prices are reckoned in piastres, and silver reals *(reales de plata)*. Eight of these reals are equivalent to a piastre, or one hundred and five sous, French money [4*s*. 4½*d*. English]. Nouv. Esp., vol. ii, p. 519, 616, and 866.

cles, and surcharged with muriat and sulphat of magnesia. As the manufacture or labor of the salt-makers was also carried on in the most irregular manner, salt was often wanted for curing meat and fish; a circumstance that has a powerful influence in these countries on the progress of industry, as the lower class of people and the slaves live on fish, and a small portion of *tasajo*. Since the province of Cumana has become dependant on the intendancy of Caraccas, the sale of salt is under the excise; and the *fanega*, which the Guayquerias sold at half a piastre, costs a piastre and a half*. This augmentation of price is slightly compensated by a greater purity of the salt, and by the facility with which the fishermen and farmers can procure it in abundance during the whole year. The salt-works of Araya yielded the treasury in 1799 a clear income of eight thousand piastres.

From these statistical accounts it results, that the manufacture of salt is of no great importtance considered as a branch of industry. It is more worthy our attention on account of the nature of the soil, which contains the salt-marshes. In order to have a clear idea of the geological connection of this muriatiferous soil with the rocks

* The fanega is sold to those Indians and fishermen who do not pay the duties (*derechos reales*), at Punta Araya for six, at Cumana for eight reals. The prices to the other tribes are, at Araya ten, at Cumana twelve reals.

of more ancient formation, we shall take a general view of the neighbouring mountains of Cumana, and those of the peninsula of Araya, and the island of Margaretta.

Three great parallel chains extend themselves from east to west. The two most northerly chains are primitive, and contain the mica-slates of Macanao, and the valley of San Juan, of Maniquarez, and of Chuparipari. These we shall distinguish by the names of *Cordillera of the island of Margaretta*, and *Cordillera of Araya.* The third chain, the most southerly of the whole, the *Cordillera of Bergantin* and of *Cocollar*, contains rocks only of secondary formation; and, what is remarkable enough, though analogous to the geological constitution of the Alps to the west of St. Gothard, the primitive chain is much less elevated than that which was composed of secondary rocks*. The sea has separated the two northern

* In New Andalusia, the *Cordillera of Cocollar* no where contains primitive rocks. If these rocks form the nucleus of this link, and rise above the level of the neighbouring plains, which is scarcely probable, we must suppose, that they are all covered with lime-stone and sand-stone. In the Swiss Alps, on the contrary, the link which is designated under the too vague denomination of lateral and calcareous link, contains primitive rocks, which, according to the valuable observations of Escher and Leopold von Buch, are often visible to the height of eight hundred or a thousand toises.

Cordilleras, those of the island of Margaretta, and the peninsula of Araya; and the small islands of Coche and of Cubagua, are remnants of the land that was submerged. Farther to the south, the vast gulf of Cariaco stretches away, like a longitudinal valley formed by the irruption of the ocean, between the two links of Araya and Cocollar, between the mica-slates and the Alpine limestones. We shall soon see, that the direction of the strata, very regular in the first of these rocks, is not quite parallel to the general direction of the gulf. In the high Alps of Europe, the great longitudinal valley of the Rhone also sometimes cuts * at an oblique angle the calcareous banks in which it has been excavated.

The two parallel links of Araya and Cocollar were connected, to the east of the town of Cariaco, between the lakes of Campoma, and Putaquao, by a kind of transverse dyke, which bears the name of Cerro de Meapire; and which in distant times, by resisting the impulse of the waves, has hindered the waters of the gulf of Cariaco from uniting with those of the gulf of Paria. Thus, in Switzerland the central chain, that which passes by the Col de Ferrex, Simplon, St. Gothard, and Spluegen, is connected on the north and the south to two lateral chains, by the mountains of Furca

* Near Sitten (Alpina, t. iv, p. 295. Bernoulli, Geogn. Uebersicht der Schweiz, p. 35—41).

and Maloya. It is pleasing to recall to mind those striking analogies, which are exhibited in both continents by the external structure of the Globe.

The primitive chain of Araya ends abruptly in the meridian of the village of Maniquarez. We shall presently show, that thirty-four leagues to the west its continuation is found in the gneiss of the *Silla of Caracas,* and in the granite of *Las Trincheras:* we here confine ourselves to what immediately relates to the environs of Cumana. The western slope of the peninsula of Araya, as well as the plains in the midst of which the castle of St. Antony rises, is covered with very recent formations of sand-stone and clay mixed with gypsum. Perhaps these same formations formerly filled the longitudinal valleys, now occupied by the ocean; and perhaps they favoured the irruption of the waters, by making less resistance than the mica-slates and Alpine lime-stone. Near Maniquarez, a breccia or sand-stone with calcareous cement, which might easily be confounded with a real lime-stone, is placed immediately on the mica-slate; while on the opposite side, near Punta Delgada, this sand-stone covers a compact, bluish gray lime-stone, almost destitute of petrifactions, and traversed by small veins of calcareous spar. This last rock is analogous to the lime-stone of the high Alps *.

* Alpenkalkstein.

The very recent sand-stone formation of the peninsula of Araya contains, first, near Punta Arenas, a stratified sand-stone, composed of very fine grains, united by a calcareous cement in small quantity; secondly, at the Cerro de la Vela, a schistose sand-stone *, without mica, and passing into slate-clay †, which accompanies coal; thirdly, on the western side, between Punta Gorda and the ruins of the castle of St. Jago, a breccia composed of an innumerable quantity of petrified sea-shells, united by a calcareous cement, in which are mingled grains of quartz; fourthly, near the point of Barigon, whence the stone employed for building at Cumana is drawn, banks of yellowish white shelly lime-stone, in which are found some scattered grains of quartz; fifthly, at Pennas negras, at the top of the *Cerro de la Vela,* a bluish gray compact lime stone, very tender, almost without petrifactions, and covering the schistose sand-stone. However extraordinary this mixture of sand-stone and compact lime-stone ‡ may appear, we cannot doubt, that these strata belong to one and the same formation. The very recent secondary rocks every where present analogous phænomena; the *molasse* of the *Pays de Vaud* contains a fetid shelly lime-stone, and the cerite lime-stone of

* Sandsteinschiefer.

† Schieferthon.

‡ Dichter kalkstein.

the banks of the Seine is sometimes mixed with sand-stone*.

The strata of calcareous breccia, which can be best examined in going along the rocky coast from Punta Gorda to the castle of Araya, are composed of an infinite number of sea shells, from four to six inches in diameter, and in part well preserved. We find they contain not ammonites, but ampullaires, solens, and terebratulæ. The greater part of these shells are mixed; the oysters and pectinites are sometimes arranged in families. The whole are easily detached, and their interior is filled with fossil madrepores and cellepores *(cellulaires)*. Formerly, on examining the banks of sand-stone, which at the northern extremity of Punta Araya are frequently bathed by the sea, I had thought, that some univalve shells, resembling the genus helix, and mixed with sea bivalve shells, belonged to the fluviatile species †. This mixture is in fact found ‡ in the lime-stone of very recent formation, that covers the chalk in the basin of Paris; but in order to verify a fact so important, we should have under our eyes the fossile shells of Araya §, and

* Cuvier and Brongniart, Geogr. min. des Environs de Paris, 1811, p. 18, 25, and 135.

† Reuss, Lehrbuch der Geognosie, t. ii, p. 441.

‡ According to the interesting observation of Mr. Beudan. (See Cuvier and Brongniart, l. c. p. 89.)

§ Specimens of sand-stone, or shelly breccia of Araya, are found among the geological series, which I sent in 1800 to the

examine them anew with that scrupulous exactness, which has been recently followed in this kind of investigation by Messrs. Lamarck, Cuvier, and Brongniart.

We have just mentioned the *mica-slates* of Maniquarez and of Chuparipari; the formation of the *Alpine lime-stone* of Punta Delgada, and of Cocollar; and that of *sand stone*, of calcareous breccia, and very recent compact lime-stone, which is found united at the western extremity of Punta Araya, as well as at the castle of St. Antonio at Cumana. We have now to speak of a fourth formation, which probably reposes * on the calcareous sandstone of Araya, I mean the *muriatiferous clay*.

This clay, hardened, impregnated with petro-

collection of the king of Spain at Madrid. There are none of them in the collections which we have deposited at Berlin, and at Paris.

* I would wish mineralogical travellers, to examine more particularly the Cerro de la Vela. The lime-stone of the Pennas Negras reposes on a slate-clay, mixed with quartzose sand; but there is no proof of the muriatiferous clay of the salt works being of a more ancient formation than this slate-clay, or of its alternating with banks of sand-stone. No well having been dug in these countries, we can have no information respecting the superposition of the strata. The banks of calcareous sand-stone, which are found at the mouth of the salt lake, and near the fishermen's huts on the coast opposite Cape Macano, appeared to me to lie beneath the muriatiferous clay.

leum, and mixed with lamellar and lenticular gypsum, is analogous to the *salzthon*, which in Europe accompanies the sal gem of Berchtesgaden, and in South America * that of Zipaquira. It is generally of a smoke gray colour, earthy, and friable; but it encloses more solid masses of a blackish brown, of a schistose, and sometimes conchoidal fracture. These fragments, from six to eight inches long, have an angular form. When they are very small, they give the clay a porphyroidal appearance. We find disseminated in it, as we have already observed, either in nests, or in small veins, selenite, and sometimes, though seldom, fibrous gypsum. It is remarkable enough, that this stratum of clay, as well as the banks of pure gem salt and the *salzthon* in Europe, scarcely ever contains shells, while the rocks adjacent offer them in great abundance.

Although the muriat of soda is not found visible to the eye in the clay of Araya, we cannot doubt of its existence. It discovers itself in large crystals, if we sprinkle the mass with rain water, and expose it to the Sun. The mere to the east of the castle of San Jago exhibits all the phænomena,

* Near Santa Fe de Bogota, this formation of *muriatiferous clay*, long neglected in the systems of geognosy, characterizes the gem salt more than the ancient secondary gypsum (aelterer Flozgyps) which reposes on the *zechstein*, or Alpine calcareous stone, as I have shown in 1798, in my work on the *Moffettes of the Mines*. (Ueber die unterirdischen Gasarten, p. 143.)

which have been observed in the salt lakes of Siberia, described by Lepechin, Gmelin, and Pallas. This mere receives however only the rain waters, which filter through the banks of clay, and unite at the lowest point of the peninsula. While the mere served as a salt-work to the Spaniards and the Dutch, it did not communicate with the sea; at present this communication has been interrupted anew, by placing faggots at the place where the waters of the ocean had made an irruption in 1726. After great droughts, crystallized and very pure muriat of soda, in masses of three or four cubic feet, are still drawn from time to time from the bottom of the mere. The salt waters of the lake, exposed to the heat of the Sun, evaporate at their surface; crusts of salt, formed in a saturated solution, fall to the bottom; and by the attraction between crystals of a similar nature and form, the crystallized masses daily augment. It is generally observed, that the water is brackish wherever meres are formed in clayey ground. It is true, that for the new salt work, near the battery of Araya, the seawater is received into pits, as in the salt marshes of the south of France; but in the island of Margaretta, near Pampatar, salt is manufactured by employing only fresh water, with which the muriatiferous clay has been lixivated.

We must not confound the salt disseminated in these clayey soils with that contained in the sands

of the seashore, which are advantageously worked on the coasts of Normandy *. These phænomena, considered in a geognostical point of view, have scarcely any thing in common. I have seen muriatiferous clay at the level of the ocean at *Punta Araya*, and at two thousand toises height in the Cordilleras of New Grenada. If in the former of these spots it lies on a very recent shelly breccia, it forms on the contrary in Austria, near Ischel, a considerable stratum † in the Alpine lime-stone, which, though equally posterior to the existence of organized beings on the Globe, is nevertheless of high antiquity, as is proved by the great number of rocks with which it is covered. We shall not call in question, that gem salt, either pure ‡ or mixed with muriatiferous clay §, may have been deposited by an ancient sea; but every thing evinces, that it was formed during an order of things, that bears no resemblance to that in which the sea at present, by a slower operation, deposits a few particles of muriat of soda on the sands of our shores. In the same manner as sulphur and coal belong to periods of formation very remote from each other, the gem salt is also

* In the bay of Avranches, and in many other parts of Europe. Chaptal, Chimie appliquée aux Arts, t. iv, p. 161.

† Buch, Geognost. Beobachtungen, t. i, p. 133.

‡ Those of Wieliczka and of Peru.

§ That of Hallein, Ischl, and Zipaquira.

found sometimes in *transition gypsum**, sometimes in the *Alpine* lime-stone†, sometimes in a muriatiferous clay lying on a very recent sandstone‡, and lastly, sometimes in a *gypsum*§ posterior to the chalk.

* Uebergangsgyps, in the transition slate of White Alley [l'Allée Blanche], and between the grauwacke and black transition lime-stone near Bex, below the Dent de Chamossaire, according to Mr. von Buch.

† At Hall in the Tyrol.

‡ At Punta Araya.

§ Gypsum of the third formation among the *secondary gypsums.* The *first* formation contains the gypsum, in which are found the brine-springs of Thuringia, and which is placed either in the Alpine lime-stone or *zechstein,* to which it essentially belongs (Freiesleben, Geognost. Arbeiten, t. ii, p. 121), or between the *zechstein* and the lime-stone of the Jura, or between the *zechstein* and the new sandstone. It is the ancient gypsum of secondary formation of Werner's school *(aelterer floezgyps),* which we almost preferably call *muriatiferous gypsum.* The *second* formation is composed of fibrous gypsum, placed either in the *molasse,* or new sand-stone, or between this and the upper lime-stone. It abounds in common clay, which differs essentially from the salzthon or muriatiferous clay. The *third* formation of gypsum is more recent than chalk. To this belong the *bony gypsum of Paris;* and, as appears from the researches of Mr. Steffens (Geogn. Aufsatsze, 1810, p. 142), the gypsum of Segeberg, in Holstein, in which gem salt is sometimes disseminated in very small nests (Jenaische Litteratur-zeitung, 1813, p. 100). The gypsum of Paris, lying between a cerite lime-stone, which covers chalk, and a sandstone without shells, is distinguished by fossile bones of quadrupedes, while the Segeberg and Lunebourg gypsums, the position of which is more uncertain, are

The new salt works of Araya have five reservoirs, or pits, the largest of which have a regular form, and two thousand three hundred square toises surface. Their mean depth is eight inches. Use is made both of the rain waters, which by filtration collect at the lowest part of the plain, and of the water of the sea, which enters by canals, or *martellières*, when the flood tide is favoured by the winds. The situation of these salt works is less advantageous, than that of the mere. The waters which fall into the latter pass over steeper slopes, washing a greater extent of ground. The natives make use of hand pumps to convey the seawater from one principal reservoir into the pits. It would nevertheless be easy enough to employ the wind as the moving power, since the breeze always blows strong on these coasts. The earth already washed is never carried away here,

characterized by the boracits which they contain. Two other formations, far anterior to the three we have just mentioned, are the transition gypsum *(uebergangsgyps)* of Aigle, and the primitive gypsum *(urgyps)* of the valley of Canaria, near Airolo. I flatter myself, that I may render some service to the small number of geologists, who prefer the knowledge of positive facts to speculation on the origin of things, in furnishing them with materials, from which they may generalize their ideas on the formation of the rocks in both hemispheres. The *relative antiquity of the formations* is the principal object of a science, which is to render us acquainted with the *construction of the Globe;* that is to say, the nature and superposition of the stony strata, which constitute the *exterior crust* of our planet.

as is the custom from time to time in the island of Margaretta; nor have wells been dug in the muriatiferous clay, to find strata richer in muriat of soda. The saltmen generally complain of want of rain; and in the new salt works it appears to me difficult to determine, what is the quantity of salt, that is owing solely to the waters of the sea. The natives estimate it at a sixth of the total produce. The evaporation is extremely strong, and favoured by the constant motion of the air; so that the salt is collected in eighteen or twenty days after the pits are filled. We found * the temperature of the salt water in the pits 32·5° while the air in the shade was 27·2°, and the sand on the coast at six inches depth, 42·5°. We were surprised to see, that the thermometer plunged into the sea rose only to 23·1°. This low temperature† is owing perhaps to the shoals, which surround the peninsula of Araya, and the island of Margaretta, and on the edges of which the lower strata of water mix with the waters of the surface.

Though the muriat of Soda is manufactured with less care in the peninsula of Araya than at the salt works of Europe, it is nevertheless purer, and contains less of earthy muriats and sulphats. We are ignorant whether this purity may be attributed to the part of the salt which is furnished by the sea;

* The 19th of August, 1799, at three in the morning.

† See above, page 142.

for though it is extremely probable, that the quantity of the salt dissolved in the waters of the ocean is nearly the same* under every zone, it is not less uncertain, whether the proportion between the muriat of soda, the muriat and sulphat of magnesia, and the sulphat and carbonat of lime be equally invariable†.

After having examined the salt works, and terminated our geodesical operations, we departed at the decline of day to sleep at an Indian hut, at some miles distance, near the ruins of the castle of Araya. We were preceded by our instruments and provision; for fatigued by the excessive heat of the air, and the reverberation of the soil, we felt no appetite in those climates, except in the

* With the exception of the Mediterranean seas, and the regions where the polar ices are formed. See above, p. 127, 128; and vol. i, p. 63. This equality in the saltness of the seawater (from 0·021 to 0·028) reminds us of the still greater uniformity, with which the oxygen is diffused throughout the aërial ocean. In both of these elements, the currents establish and preserve the equilibrium between the parts dissolved or mingled with each other. (Bayly and Cook, Original Observ., p. 345.)

† Lavoisier found, that in the waters of the sea, near Dieppe, the quantity of muriat of soda is to that of the other salts as 2·36 is to 1. According to Messrs. Bouillon-Lagrange and Vogel, this proportion is as 2·60 to 1. See the judicious observations of Dr. Thomson, in his Chemistry, t. vi, p. 346—357. (Henry, Phil. Trans., 1810, p. 97 and 122; and Annales de Chémie, t. lxxxvii, p. 193—208.)

morning, or in the cool of the evening. Directing our course toward the south, we traversed first the plain covered with muriatiferous clay, and stripped of vegetation; then two chains of hills of sandstone, between which is the mere or laguna. Night overtook us while we were in a narrow path, bordered on one side by the sea, and on the other by a range of perpendicular rocks. The tide was rising rapidly, and narrowed the road at every step. We at length arrived at the foot of the old castle of Araya, where we enjoyed a prospect that had in it something lugubrious and romantic. Here however, neither the coolness of a deep and gloomy forest, nor the grandeur of the vegetable forms, heightens the beauty of these ruins; which, standing single on a bare and arid mountain, crowned with agave, with columnar cactus, and thorny mimosas, resemble less the works of man, than those masses of rock that were ruptured at the first revolutions of the Globe.

We were desirous of stopping to admire this majestic spectacle, and observe the setting of Venus, the disk of which appeared at intervals between the yawning crannies of the castle; but the muleteer, our guide, was parched with thirst, and pressed us earnestly to return. He had long perceived, that we had lost our way; and as he hoped to work on our fears, he continually warned us of the danger from tigers and rattlesnakes. Venomous reptiles were in fact very common near

the castle of Araya; and two jaguars had been lately killed at the entrance of the village of Maniquarez. If we might judge from their skins, which had been preserved, their size was not less than that of the Indian tiger. We vainly represented to our guide, that those animals did not attack men, on coasts where the goats furnished them with abundant food; we were obliged to yield, and return. After having proceeded three quarters of an hour along a shore covered by the tide, we were joined by the negro, who carried our provision. Uneasy at not seeing us arrive, he was come to meet us, and led us across a wood of nopals to a hut inhabited by an Indian family. We were received with that cordial hospitality, which is met with in this country among people of every tribe. The hut in which we slung our hammocks was very clean; and there we found fish, plantains, and what in the torrid zone is preferable to the most sumptuous food, excellent water.

The next day at sunrise, we found, that the hut in which we had passed the night formed part of a group of small dwellings on the borders of the salt lake, the remains of a considerable village which had formerly stood near the castle. The ruins of a church appeared buried in the sand, and covered with brushwood. When in 1765, to save the expense of the garrison, the castle of Araya was totally dismantled, the Indians and

Mulattoes, who were settled in the neighbourhood, emigrated by degrees to reside at Maniquarez, at Cariaco, and in the suburb of the Guayquerias at Cumana. A small number, bound from affection to their native soil, remained in this wild and barren spot. These poor people live by catching fish, which is extremely abundant on the coast and the neighbouring shoals. They appear satisfied with their condition, and think it strange when they are asked why they have no gardens or culinary vegetables. Our gardens, they reply, are beyond the gulf; when we carry our fish to Cumana, we bring back plantains, cocoa nuts, and cassava. This system of economy, grateful to idleness, is followed at Maniquarez, and throughout the whole peninsula of Araya. The chief wealth of the inhabitants consists in goats, which are of a very large and very fine breed, and rove in the fields like those at the Peak of Teneriffe; they are become entirely wild, and are marked like the mules, because it would be difficult to recognize them from their physiognomy, their color, or the disposition of their spots. The wild goats are of a brownish yellow, and are not varied in their color like domestic animals. If in hunting a colonist kills a goat, which he does not consider as his own property, he carries it immediately to the neighbour, to whom it belongs. During two days we heard it every where spoken of as an example of strange

perverseness, that an inhabitant of Maniquarez had lost a goat, on which it was probable that a neighbouring family had regaled themselves. These traits, which are proofs of a great purity of morals in the lower class, are often exhibited in New Mexico, in Canada, and in the countries situate to the west of the Alleghanies.

Among the Mulattoes, whose huts surround the salt-lake, we found a shoemaker of Castilian descent. He received us with the air of gravity and selfsufficiency, which in those climates characize almost all who are conscious of possessing some peculiar talent. He was employed in stretching the string of his bow, and sharpening his arrows to kill birds. His trade of a shoemaker could not be very lucrative in a country, where the greater part of the inhabitants go barefoot; and he only complained, that, on account of the dearness of European gunpowder, a man of his quality was reduced to employ the same weapons as the Indians. He was the sage of the plain, he understood the formation of the salt by the influence of the Sun and the full Moon, the symptoms of earthquakes, the marks by which mines of gold and silver are discovered, and the medicinal plants, which he divided, like all the other colonists from Chili to California, into *hot and cold**. Having collected the traditions of the

* Exciting or debilitating, sthenic or asthenic of Brown's system.

country, he gave us some curious accounts of the pearls of Cubagua, objects of luxury, which he treated with the utmost contempt. To show us how familiar to him were the sacred writings, he took a pride in quoting to us Job, who preferred wisdom to all the pearls of the Indies. His philosophy was circumscribed to the narrow circle of the wants of life. A very strong ass, able to carry a heavy load of plantains to the *embarcadere*, was the object of all his wishes.

After a long discourse on the emptiness of human grandeur, he drew from a leathern pouch a few very small and opake pearls, which he forced us to accept, enjoining us at the same time to note on our tablets, that a poor shoemaker of Araya, but a white man, and of noble Castilian race, had been enabled to give us what on the other side of the sea* was sought for as a very precious thing. I acquit myself rather late of the promise I made this honest man; and I am happy to add, that his disinterestedness did not permit him to accept of the slightest retribution. The *Pearl Coast* presents, it is true, the same aspect of misery as the countries of *gold and diamonds*, Choco and Brasil; but misery is not there attended with that immoderate desire of gain, which is excited by mineral riches.

* *Por alla, or, del otro lado del charco* (properly, " beyond the great mere"), a figurative expression, by which the people in the Spanish colonies denote Europe.

The *pearl aronde* (*avicula margaritifera*, Cuvier) abounds on the shoals, which extend from Cape Paria to that of Vela*. The island of Margaretta, Cubagua, Coche, Punta Araya, and the mouth of the Rio la Hacha, were celebrated in the sixteenth century, as the Persian Gulf, and the island Taprobane were among the ancients†. It is not just to say, as several historians have asserted, that the natives of America were unacquainted with the luxury of pearls. The first Spaniards who landed in Terra Firma found the savages decked with necklaces and bracelets; and among the civilized people of Mexico and Peru pearls of a beautiful form were extremely sought after. I have published a dissertation on the statue of a Mexican priestess in basalt‡, whose headdress, resembling the *calantica* of the heads of Isis, is ornamented with pearls. Las Casas and Benzoni have described, but not without some

* Costa de las Perlas, Herera, Dec. 1, lib. vii, c. 9. Gomara, Hist. c. 78. Petri Bembi Cardin. Hist. Venetæ lib. xii (1555), p. 83. Cancellieri, Diss. sopra Christ. Colombo (1809), p. 101.

† Strabo, lib. xv, (pag. Oxon. 1017) Plin., lib. ix, c. 35, lib. xii, c. 18. Solin. Polyhist. c. 66 (ed. 1518, p. 316 and 324), and above all, Athen. Deipnosoph. lib. iii, c. 45 (ed. Schweighæuser, 1801, t. i, p. 360—367), and Animadvers. in Athen. t. ii, p. 126.

‡ Picturesque Atlas, pl. 1, and 2. [See vol. xiii of this edition, p. 43.]

exaggeration, the cruelties which were exercised on the unhappy Indian slaves and Negroes employed in the pearl fishery. At the beginning of the conquest, the island of Coche alone furnished the value of fifteen hundred marks of pearls a month.

The *quint*, which the king's officers drew from the produce of pearls, amounted to fifteen thousand ducats; which, according to the value of the metals in those times, and the extensiveness of the contraband trade, might be considered as a very considerable sum. It appears, that till 1530 the value of the pearls sent to Europe amounted yearly on an average to more than eight hundred thousand piastres. In order to judge of the importance of this branch of commerce to Seville, Toledo, Antwerp, and Genoa, we should recollect, that at the same period the whole of the mines of America* did not furnish two millions of piastres; and that the fleet of Ovando seemed to be of immense wealth, because it contained nearly two thousand six hundred marks of silver. Pearls

* I have endeavoured to prove in another place (Nouv. Esp. t. ii, p. 652), by a history at large of the ancient mines of Mexico and Peru, the accuracy of the ideas spread throughout Europe on the exhausted state of the metalliferous mines of America, on their decreasing richness, and on the quantity of metals which Spain received during the reigns of Charles the fifth and Philip the second.

were so much the more sought after, as the luxury of Asia had been introduced into Europe by two ways diametrically opposite; that of Constantinople, where the Paleologi wore garments covered with strings of pearls; and that of Grenada, the residence of the Moorish kings, who displayed at their court all the luxury of the East. The pearls of the East Indies were preferred to those of the West; but the number of the latter which circulated in commerce was not less considerable in the times which immediately followed the discovery of America. In Italy as well as in Spain, the islet of Cubagua became the object of numerous mercantile speculations.

Benzoni* relates the adventure of one Lewis Lampagnano, to whom Charles the Fifth granted the privilege of proceeding with five carvels to the coasts of Cumana, to fish for pearls. The colonists sent him back with this bold answer: "That the Emperor, too liberal of what was not his own, had not the right to dispose of the oysters, which live at the bottom of the sea."

The pearl fishery diminished rapidly toward the end of the sixteenth century; and, according to

* La Hist. del Mondo Nuovo, p. 34. Lewis Lampagnano, a relation of the assassin of the Duke of Milan, Galeazzo Maria Sforza, could not pay the merchants of Seville, who had advanced the money for his voyage; he remained five years at Cubagua, and died in a fit of insanity.

Laet, it had long ceased in 1683*. The industry of the Venetians, who imitated fine pearls with great exactness, and the frequent use of cut diamonds†, rendered the fisheries of Cubagua less lucrative. At the same time the oysters which yielded the pearls became scarcer, not, as it is believed from a popular tradition, because these animals, frightened by the noise of the oars, conveyed themselves elsewhere; but because their propagation had been prevented from the imprudent destruction of the shells by thousands. The *pearla ronde* is of a much more delicate constitution than the greater part of the other acephalous molluscæ. At the isle of Ceylon, where, in the bay of Condeatchy, the fishery employs six hundred divers, and where the annual produce is more than half a million of piastres, it has vainly been attempted to transplant the animals to other parts of the coast. The government permits fishing there only during a single month; while at Cu-

* "Insularum Cubaguæ et Coches quondam magna fuit dignitas, quum unionum captura floreret: nunc, illa deficiente, obscura admodum fama." Læt. Nov. Orbis, p. 669. This accurate compiler, speaking of Punta Araya, adds, this country is so forgotten, "ut vix ulla alia Americæ meridionalis pars hodie obscurior sit."

† The cutting of diamonds was invented by Lewis de Berquen, in 1456, but it became common only in the following century.

bagua the bank of shells was fished at all seasons. To form an idea of the destruction of the species caused by the divers, we must remember, that a boat sometimes collects, in two or three weeks, more than thirty-five thousand oysters. The animal lives but nine or ten years; and it is only in its fourth year, that the pearls begin to show themselves. In ten thousand shells there is often not a single pearl of value*. Tradition states, that on the bank of Margaretta the fishermen opened the shells one by one; in the island of Ceylon, the animals are thrown into heaps, to rot in the air; and to separate the pearls, which are not attached to the shell, the animal pulp is washed, as the miners do the sands that contain grains of gold, tin, or diamonds.

At present Spanish America furnishes no other pearls for trade than those of the gulf of Panama, and the mouth of the rio de la Hacha. On the shoals that surround Cubagua, Coche, and the island of Margaretta, the fishery is as much neglected as on the coasts of California†. It is believed at Cumana, that the pearl-*aronde* has

* Cordiner, Description of Ceylon, vol. ii, p. 187.

† Nouv. Esp. t. i, p. 313; and t. ii, p. 465. I am astonished at never having heard in the course of my travels of pearls found in the fresh water shells of South America, though several species of the *unio* genus abound in the rivers of Peru.

greatly multiplied after two centuries of repose *; and it is asked, why the pearls found at present in shells which are entangled† in the fishermen's nets are so small, and have so little brilliancy, while on the arrival of the Spaniards they were so extremely beautiful among the Indians, who doubtless had not given themselves the trouble of diving to collect them. The problem is so much the more difficult to solve, as we are ignorant whether earthquakes have altered the nature of the bottom of the sea, or whether the changes of the submarine currents may have had an influence either on the temperature of the water, or on the abundance of certain molluscæ on which the *aronde* feeds.

On the 20th in the morning, our host's son, a young and very robust Indian, conducted us over Barigon and Caney to the village of Maniquarez, which was four hours walk. From the effect of the reverberation of the sands, the thermometer kept up to 31° 3′. The cylindric cactus, which bordered the road, gave the landscape an appearance of verdure, without yielding either coolness or shade. Before our guide had travelled a league, he sat himself down at every instant,

* In 1812, some new attempts were made at Margaretta for the fishing of pearls.

† The inhabitants of Araya sometimes sell these small pearls to the retail dealers of Cumana. The ordinary price is a piastre a dozen.

and wished to repose under the shade of a fine tamarind tree near Casas de la Vela, to wait the approach of the night. I dwell on this characteristic trait, which we observed every time that we travelled with Indians, and has given rise to very false ideas of the physical constitutions of the different races of men. The copper-coloured native, more accustomed to the burning heat of the climate, than the European traveller, complains more, because he is stimulated by no interest. Money is without attraction for him; and if he permits himself to be tempted by gain for a moment, he repents of his resolution as soon as he is on the road. The same Indian, who complains, when in herbalizing we load him with a box filled with plants, rows his canoe fourteen or fifteen hours together, against the swiftest current, because he wishes to return to his family. In order to form a true judgment of the muscular force of the people, we should observe them in circumstances, where their actions are determined by a will equally energetic.

We examined the ruins of San Jago*, the construction of which is remarkable for its extreme solidity. The walls of free-stone are five feet

* On the map accompanying Robertson's History of America we find the name of this castle confounded with that of Nueva Cordoba. We have already observed, that this latter denomination was formerly synonimous with Cumana. (Herrera, p. 14.)

thick: they have been blown up by mines; but we still found masses of seven or eight hundred feet square, which have scarcely a crack in them. Our guide showed us a cistern *(el aljibe)* thirty feet deep, which, though much damaged, furnishes water to the inhabitants of the peninsula of Araya. This cistern was finished in 1681, by the governor Don Juan de Padilla Guardiola, the same who built at Cumana the small fort of Santa Maria*. As the basin is covered with an arched vault, the water, which is of an excellent quality, keeps very cool, and has no conferva, which, while it decomposes the carburet of hydrogen, harbours worms and small insects. It had been believed for ages, that the peninsula of Araya was entirely destitute of springs of fresh water; but in 1797, after many useles researches, the inhabitants of Maniquarez succeeded in discovering some.

In crossing the arid hills of Cape Cirial, we perceived a strong smell of petroleum. The wind blew from the side where the springs of this substance are found, and which were mentioned by the first historians of these countries†. Near the village of Maniquarez, the mica-slate‡ comes out from below the secondary rock, forming a chain of

* Castillo de Santa Maria, or Fuerte de N. S. de la Cabeza. See above, page 196. (Caulin.,p. 284.)

† Oviedo, Lib. 19, cap. 1. "Resinous, aromatic, and medicinal liquor."

‡ Piedra pelada of the Creoles.

mountains from one hundred and fifty to one hundred and eighty toises in height. The direction of the primitive rock near Cape Sotto is from north east to south west; its strata incline fifty degrees to the north west* The mica slate is silvery white, of lamellar and undulated texture, and contains garnets. Strata of quartz, the thickness of which varies from three to four toises, traverse the mica-slate, as we may observe in several ravines hollowed out by the waters. We detached with difficulty a fragment of cyanite† from a block of splintered and milky quartz, which was isolated on the shore. This was the only time we found this substance in South America‡.

The potteries of Maniquarez, celebrated from time immemorial, form a branch of industry, which is exclusively in the hands of the Indian women. The fabrication is still carried on according to the method used before the conquest. It indicates both the infancy of the art, and that stability of manners, which is the characteristic of all the natives of America. Three centuries have been insufficient, to introduce the potter's-wheel on

* Hours three and four of the Freiberg compass. Very near the village of Maniquarez, the strata vary to hours eleven and twelve, inclining often to the south west.

† Disthène, Haüy.

‡ In New Spain, the cyanite has been discovered only in the province of Guatimala, at Estancia Grande. Del Rio, Tablas min., 1804, p. 27.

a coast, which is not above thirty or forty days sail from Spain. The natives have some confused notions with respect to the existence of this machine, and they would make use of it if they had a model. The quarries whence they draw the clay are half a league to the east of Maniquarez. This clay is produced by the natural decomposition of a mica-slate reddened by oxid of iron. The Indian women prefer the part most abounding in mica; and with great address fashion vessels two or three feet in diameter, giving them a very regular curve. As they are not acquainted with the use of ovens, they place twigs of desmanthus, cassia, and the arborescent capparis, around the pots, and bake them in the open air. To the east of the quarry that furnishes the clay is the ravine of la Mina. It is asserted, that, a short time after the conquest, some Venetians extracted gold from the mica-slate. It appears, that this metal was not collected in veins of quartz, but was found disseminated in the rock, as it is sometimes in granite and gneiss.

At Maniquarez we met with some creoles, who had been hunting at Cubagua. Deer of the small breed are so common in this uninhabited islet, that a single person may kill three or four in a day. I know not by what accident these animals have got thither, for Laet and other chroniclers of these countries, speaking of the foundation of New Cadiz, mention only the great abundance of rabbits. The *venado* of Cubagua belongs to one of those numer-

ous species of small American deer, which zoologists have long confounded under the vague name of *cervus mexicanus.* It does not appear to be the same as the *hind of the savannahs* of Cayenne, or the *guazuti* of Paraguay*, which live also in herds. Its colour is a brownish red on the back, and white under the belly; and it is spotted like the axis. In the plains of Cari we were shown, as a thing very rare in these burning climates, a variety quite white. It was a female of the size of the roebuck of Europe, and of a very elegant shape. White varieties are found in the New Continent even among the tigers. Mr. d'Azara has seen a jaguar, the skin of which was wholly white, except the shade only, as it might be termed, of a few circular spots.

Of all the productions on the coasts of Araya, that which the people consider as the most extraordinary, we may even say the most marvellous, is the stone of the eyes, *piedra de los ojos.* This calcareous substance is the subject of every conversation; according to the natural philosophy of the natives, it is both a stone and an animal. It is found in the sand, where it is motionless; but placed singly on a polished surface, for instance on a pewter or earthen plate, it moves when excited

* Pennant's Quadrupeds, p. 119, n. 52. Azara, Essay on the Quadrupeds of Paraguay, vol. i, p. 77. Cuvier on the fossile ruminating Animals, in the Ann, du Musée, t. xii, p. 365.

by lemon juice. Placed in the eye, the pretended animal turns on itself, and expels every other foreign substance, that has been accidentally introduced. At the new salt works, and at the village of Maniquarez, the *stones of the eyes** were offered us by hundreds, and the natives were earnest to show us the experiment of the lemon juice. They wished to put sand into our eyes, in order that we might ourselves try the efficacy of the remedy. It was easy to see, that these stones are thin and porous opercula, which have formed part of small univalve shells. Their diameter varies from one to four lines. One of their two surfaces is plane, and the other convex. These calcareous opercula effervesce with lemon juice, and put themselves in motion in proportion as the carbonic acid is disengaged. By the effect of a similar reaction, loaves placed in an oven move sometimes in a horizontal plane; a phænomenon that has given occasion, in Europe, to the popular prejudice of *enchanted ovens*. The *piedras de los ojos*, introduced into the eye, act like small pearls, and different round grains employed by the American savages to increase the flowing of tears. These explanations were little to the taste of the inhabitants of Araya. Nature has the appearance of greatness to man in proportion as she is veiled in mystery, and the

* They are found in the greatest abundance near the battery at the point of Cape Araya.

philosophy of the people rejects every thing that bears a character of simplicity.

Proceeding along the southern coast, to the east of Maniquarez, we find running out into the sea very near each other, three strips of land, which bear the names of Punta de Soto, Punta de la Brea, and Punta Guaratarito. In these parts the bottom of the sea is evidently formed of a mica-slate; and it is from this rock, that, near Cape de la Brea *, but at eighty feet distance from the shore, a spring of naphtha rises, the smell of which spreads itself into the interior of the peninsula. You must wade into the sea up to the waist, to examine this interesting phænomenon. The waters are covered with zostera; and in the midst of a very extensive bank of weeds (d'herbes), we distinguish a free and circular spot of three feet diameter, on which swim a few scattered masses of ulva lactuca. Here the springs are found. The bottom of the gulf is covered with sand; and the petroleum, which, from its transparency, and its yellow colour, resembles the real naphtha, rises in jets, accompanied by air bubbles. On treading down the bottom with the foot, we perceive, that these little springs change their place. The naphtha covers the surface of the sea to more than a thou-

* *Tar Cape.* The greatest reservoir of petroleum *(chapapote)* is that of the island of Trinidad, which has been described by Span, Hatchet. Anderson, and Dauxion Lavaysse. (Voy. aux Isles de Trinidad and de Tabago, t. i, p. 24 to 30.)

sand feet distance. If we suppose the dip of the strata to be regular, the mica-slate must be but a few toises below the sand.

We have already observed, that the muriatiferous clay of Araya contains solid and friable petroleum. This geological connection between the muriat of soda and the bitumens is evident wherever there are mines of gem salt or salt springs: but a very remarkable fact is the existence of a fountain of naphtha in a primitive formation. All those hitherto known belong to secondary mountains*; and this situation of them seemed to favour the idea, that all mineral bitumens were owing to the destruction of vegetables and animals †, or to the burning of coal. In the peninsula of Araya, the naphtha flows from the primitive rock itself; and this phænomenon acquires new importance, when we recollect, that the same primitive rocks contain the subterraneous fires, that on the brink of burning craters the smell of petroleum is perceived from time to time, and that the greater part of the hot springs of America rise from gneiss and micaceous schist.

After having examined the environs of Maniquarez, we embarked at night in a fishing boat for

* Pietra mala; Fanano; Mont-Zibio; Amiano, where are the springs that furnish the naphtha employed in lighting the city of Genoa; Bakou; &c.

† Hatchet, in the Trans. of the Lin. Society, 1798, p. 129.

Cumana. Nothing is a better proof of the calmness of the sea of these regions, than the extreme smallness and wretched state of these boats, which carry a very high sail. That we chose as the least damaged was so leaky, that the pilot's son was constantly employed in baling out the water with a *tutuma*, or shell of the crescentia cujete (calebash). It often happens in the gulf of Cariaco, and especially to the north of the peninsula of Araya, that the canoes loaded with cocoas are overset in sailing too near the wind, and against the waves. These accidents are to be dreaded only by passengers little accustomed to swimming; for if the canoe be managed by an Indian fisherman and his son, the father sets right the boat, and empties it of water, while the son swims about collecting the cocoa nuts. In less than a quarter of an hour, the canoe is again under sail, without a single complaint on the part of the Indian, who meets the accident with calm unshaken indifference.

The inhabitants of Araya, whom we visited a second time on returning from the Orinoco, did not forget, that their peninsula was one of the points first peopled by the Spaniards. They love to talk of the pearl fishery; of the ruins of the castle of St. Jago, which they hope to see some day rebuilt; and of every thing that recalls to mind the ancient splendour of those countries. In China and Japan those inventions are considered as recent, which have not been known above two thousand years;

in the European colonies an event appears extremely old, if it dates back three centuries, or about the period of the discovery of America.

This absence of memorials, which characterizes new nations, both in the United States, and in the Spanish and Portuguese possessions, is well worthy of attention. The void has not only something painful to the traveller, who finds himself deprived of the most delightful enjoyments of the imagination; it has also an influence on the greater or less powerful ties, that bind the colonist to the soil on which he dwells, to the form of the rocks surrounding his hut, and to the trees which have shaded his cradle.

Among the ancients, the Phœnicians and the Greeks, for instance, traditions and national remembrances passed from the mother-country, to the colonies; where, perpetuated from generation to generation, they never ceased to have a favourable influence on the opinions, the manners, and the policy of the colonists. The climates of these first establishments beyond the seas differed but little from those of the mother country. The Greeks of Asia Minor and Sicily were not strangers to the inhabitants of Argos, Athens, and Corinth, from whom they boasted their descent. A great analogy of manners contributed to cement the union, which was founded on religious and political interests. The colonists frequently offered the first fruits of their harvests in the temples

of the metropolis; and when by some sinister accident the sacred fire was extinguished on the altars of Hestia, messengers were sent from the farther part of Ionia, to rekindle the flame at the Prytaneion of Greece*. Every where, in Cyrene, as well as on the banks of the Mæotis, the inhabitants carefully preserved the traditions of the mother country. Other remembrances equally fitted to affect the imagination, were attached to the colonies themselves. They had their sacred groves, their tutelary divinities, their local mythology, and, what gave life and durability to the fictions of the first ages, they had poets, who extended their glory as far as the metropolis itself.

These advantages, and many others, are wanting in modern colonies. The greater part are settled in a zone, where the climate, the productions, the aspect of the sky, and the scenery of the landscape, differ altogether from those of Europe. The colonist vainly bestows on mountains, rivers, and vallies, those names, which call to his remembrance the sites of the mother country; these names soon lose their attraction, and have no meaning with the generations that succeed. Under the influence of an exotic nature, habits are generated, that are adapted to new wants; national remembrances are insensibly effaced; and

* *Clavier, Hist. des premiers Temps de la Grèce*, t. ii, p. 67. (t. i, p. 188.)

those that remain, like phantoms of the imagination, have neither "a local habitation, nor a name." The glory of Don Pelagio, and of the Cid Campeador, has penetrated even to the mountains and forests of America: the people sometimes pronounce these illustrious names; but they form no other notions of their existence, than that of heroes belonging to some vague period of fabulous times.

This foreign firmament, this contrast of climate, this physical conformation of the country, have a more decided effect on the state of society in the colonies, than the absolute distance of the mother country. Such is the improved state of modern navigation, that the mouths of the Orinoco and of the Rio de la Plata seem more contiguous to Spain, than in former times Phasis and Tartessus did to the coasts of Greece and Phœnicia. We even observe, that, in regions equally remote, the manners and traditions of Europe are more habitually preserved in the temperate zone, and on the ridges of the equatorial mountains, than in the plains of the torrid zone. Similarity of situation contributes in a certain degree to maintain more intimate connections between the colonists and the metropolis. This influence of physical causes in the state of infant societies is particularly manifested, when it concerns portions of people of the same race, who have been recently separated from each other. In traversing the regions of the New World, we imagine that we find more traditions,

a greater freshness in the remembrances of the mother country, wherever the climate permits the cultivation of corn. In this point of view, Pennsylvania, New Mexico, and Chili, resemble those elevated plains of Quito and New Spain, which are covered with oaks and with firs.

Among the ancients, history, religious opinions, and the physical state of a country, were linked together by indissoluble ties. The colonist must have renounced the faith transmitted to him by his ancestors, could he have forgotten the aspect of the sites, and the ancient revolutions of the mother country. With modern nations, religion no longer wears, if I may use the expression, a local tint. Christianity, in furnishing new ideas, and opening a wider range to the exercise of the intellectual faculties; in declaring, that all nations of men that dwell on the face of the Earth are made of one blood, and members of the same family; has weakened every exclusive sentiment, and has spread through both Worlds the ancient traditions of the East with those that are peculiarly its own. Nations of different origin, and discordant idioms, have received from this common institution common remembrances; and the establishment of the missions, after having laid the foundations of civilization in a great part of the New Continent, has given to cosmogonic and religious ideas a marked preeminence over remembrances that were merely national.

But this is not all; the American colonies are almost all founded in countries, where the generations that are extinct have left scarcely any trace of their existence. At the mouth of the Rio Gila, on the banks of the Missouri, in the plains that extend to the east of the Andes, traditions date no farther back than a century. At Peru, Guatimala, and Mexico, ruins of edifices, historical paintings, and monuments of sculpture, attest, it is true, the ancient civilization of the natives; but in a whole province we find very few families, who have just ideas relative to the history of the Incas, and of the Mexican princes. The native has preserved his language, his dress, and his national character; but the disappearance of the quippus, and of symbolic paintings, the introduction of christianity, and other circumstances, which I have elsewhere developed, have gradually extinguished historical and religious traditions. On the other hand, the colonist of European race disdains whatever relates to the conquered people. Placed between the remembrances of the mother country, and those of the country where he first drew his breath, he considers both with equal indifference; and in a climate where the equality of seasons renders the succession of years almost imperceptible, he abandons himself to the enjoyments of the present moment, and scarcely casts back a look on the times that are past.

What a difference also between the monotonous

history of modern colonies, and the varied picture exhibited by the legislation, the manners, and the political revolutions of the colonies of the ancients! Their intellectual culture, modified by the different forms of their government, often excited the envy of the mother countries; and by this happy rivalship arts and letters attained the highest degree of splendor in Ionia, in Græcia Magna, and in Sicily. In our days, on the contrary, the colonies have neither history, nor national literature. Those of the New World have never had powerful neighbours, and there the state of society has undergone only imperceptible changes. Without political existence, these settlements, formed for commerce or for agriculture, have taken but a passive part in the great agitations of the World. The history of modern colonies affords but two memorable events: their foundation, and their separation from the mother country. The first of these events is rich in remembrances, which essentially belong to the countries occupied by the colonists; but, far from recalling to mind the peaceful progress of industry, or the improvement of colonial legislation, acts of violence and injustice only protrude themselves on the scene. What charm can those extraordinary times present, when, under the reign of Charles the Fifth, the Castilians displayed more courage than virtue? and when chivalrous honour, like the glory of arms, was sullied by fanaticism and the thirst of

riches? The colonists, of mild character, are freed by their situation from national prejudices, appreciate at their just value the exploits of the conquest. The men who figured at that period were Europeans; they were the soldiers of the mother country; they appear as strangers to the inhabitants of the colonies, for three ages have been sufficient to dissolve the ties of blood. Among the *conquistadores*, no doubt, some upright and generous men may be found; but, mingled in the mass, they have been unable to escape the general proscription.

I believe, that I have indicated the principal causes, which in modern colonies have dispelled national remembrances, without nobly filling their place by others relative to the country newly inhabited. This circumstance, we cannot sufficiently repeat, exercises a great influence over the situation of the colonists. In the stormy times of a political regeneration, they find themselves isolated, like a people who, renouncing the study of its annals, should cease to derive lessons of wisdom from the misfortunes of preceding ages.

END OF VOL. II.

W. Pople, Printer, 67, Chancery Lane.

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VOL. 2